Agence Française de Développement

AFD Contract No. EEA-2020-370

Design study for the creation of a Water Fund for Mombasa City

Technical Report

March 2022

Prepared by:

Anchor Environmental Consultants (Pty) Ltd.

in collaboration with FutureWater

PREFACE AND ACKNOWLEDGEMENTS

This report was commissioned by The *Agence Française de Développement* (AFD) and The Nature Conservancy (TNC) to develop a business case for the investment in proposed nature-based solutions for the Mwache Dam catchment.

The study was carried out by Anchor Environmental Consultants, with hydrological modelling by Future Water.

With special thanks to George Maina, Caroline Lumosi, Bob Okello, TNC; Thomas Bouisse, Roger Luhalwe, Guillaume Polge, AFD; Chris White, Jess Wood, Petrina Rowcroft, Lilly Kipchumba, AECOM; Clarice Wambua, Kieti Advocates LLP; Sophia Burke, AmbioTEK; Chris Tuite, MWCT; and the following stakeholders: Ministry of Water, Sanitation and Irrigation; Water Resources Authority; Water Services Regulatory Board; Coast Development Authority; Coast Waterworks Development Agency; County Governments of Mombasa, Kwale and Taita-Taveta; Mombasa Water Supply and Sanitation Company; Jumuiya Ya Kaunti Za Pwani.

EXECUTIVE SUMMARY

PART 1. BACKGROUND AND STUDY CONTEXT

1. Introduction

Many cities and regions around the world face increasing pressures on their water supplies and other hydrological ecosystem services as a result of growth in urban demand and/or degradation of water source areas such as mountain catchments. Water Funds provide a means to improve water security by financing nature-based solutions in water source areas. The *Agence Française de Développement* (AFD) and The Nature Conservancy (TNC) have identified an opportunity to establish such a fund for Mombasa, the second-largest city in Kenya. The proposed "Mombasa Water Fund" (MWF; a provisional name) would be designed to improve water security for Mombasa City and a number of other smaller towns in southeastern Kenya that depend on the same water sources. The MWF would aim to reduce land degradation in water source areas to ensure long-term sustainability of the benefits from major water supply infrastructure investments that are currently under construction in order to address major water supply shortages in this region.

This study builds on the work of a pre-feasibility study and related activities undertaken by TNC, the World Bank's Kenya Water Security and Climate Resilience Project (KWSCRP-2), and the AECOM/GNI Plus's Chyulu Hills Water PES scheme project. The aim of this study is to provide a clear plan to the AFD, TNC and local actors as to how to move forward with the creation of the MWF. To that end, it assesses the technical, financial, economic and socio-economic benefits and challenges, and identifies potential governance and sustainable financing models for the MWF. The components of the study are summarised in Figure I. These components, which incorporate input from engagement with stakeholders, are interwoven into the report structure.

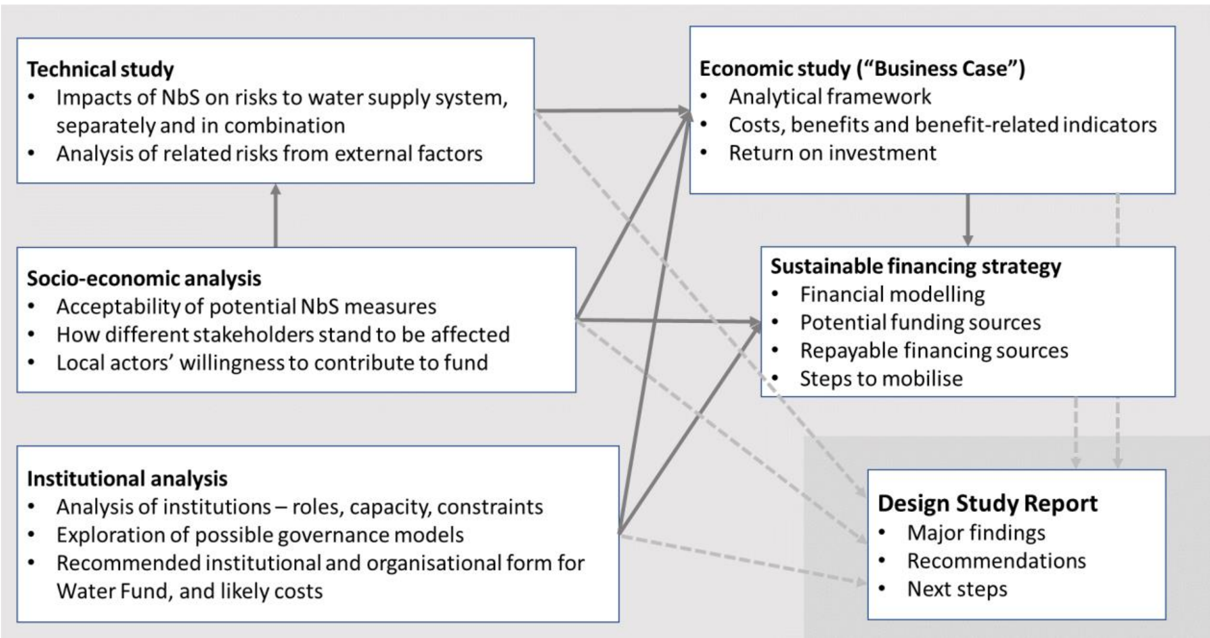


Figure I. Summary of the study components

The MWF is primarily focused on the Mwache Dam catchment area and the Mzima Springs water recharge area (Figure II). The technical aspect of this study focused on the Mwache Dam catchment area, since nature-based solutions for the Mzima Springs recharge area were already being investigated and designed under a separate initiative being undertaken by GNIplus in collaboration with AECOM.

Their study has furnished a description of the recharge area, its hydrology, and the expected effect of implementing natural resource management measures focused on overgrazing and woody resource use on the recharge and yield of the Mzima Springs. These estimates were used in combination with the proposed Mwache Dam catchment interventions to evaluate their combined impacts on water security.

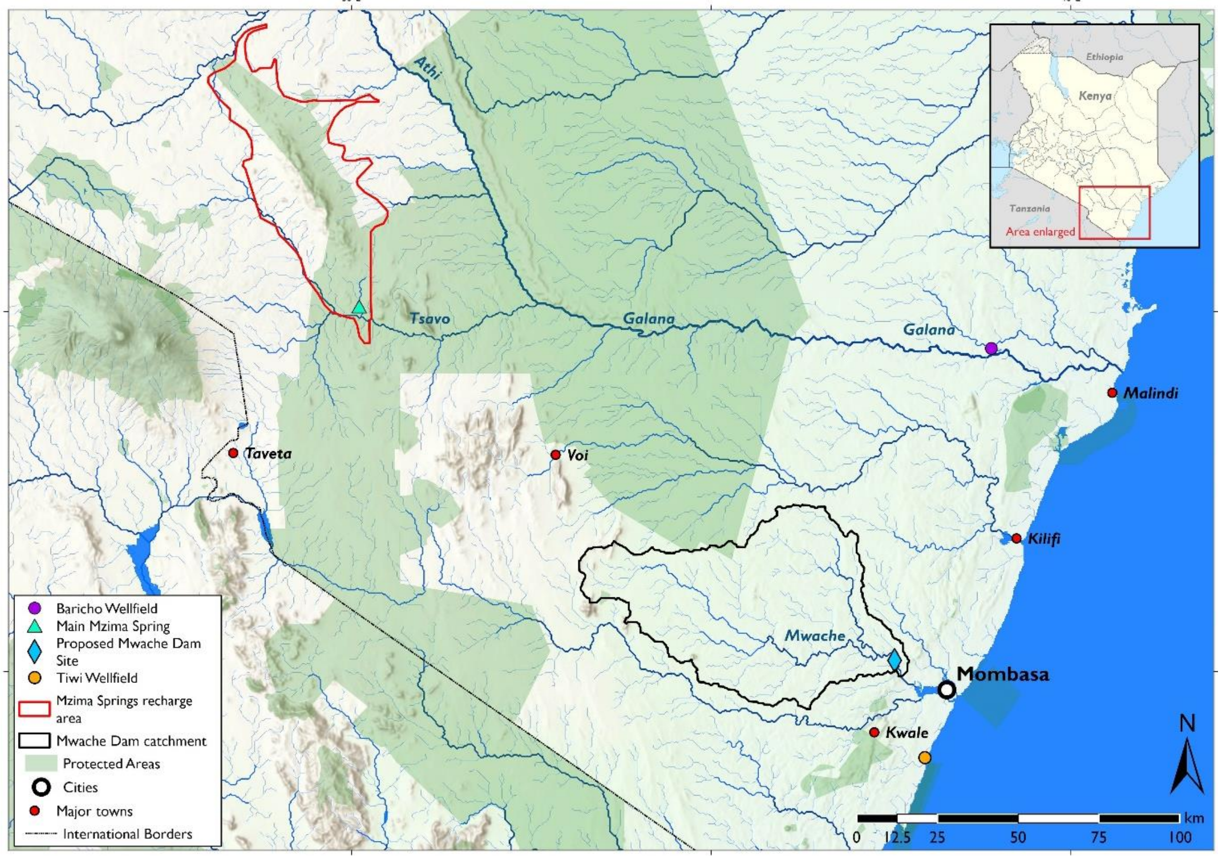


Figure II. The Mwache Dam catchment and recharge area of the Mzima Springs as key components of the Mombasa water supply system, which currently comprises the springs and wellfields shown. Note that the boundary of the recharge area is approximate.

2. Water Funds

Water funds provide a means by which finance and assistance from downstream hydrologic service beneficiaries (e.g. water service providers and consumers) and donors (motivated by developmental and/or biodiversity conservation benefits) can be channelled to the actors that implement management changes or accommodate conservation actions in important water catchment areas. Water funds thus provide a financing and governance mechanism for linking downstream water consumers with upstream land users, typically taking the form of a public-private partnership. A key premise of the Water Fund approach is that often it is cheaper to prevent water problems at the source than to address them later. Funding is also used to support economic opportunities that enhance livelihoods for local communities, including agricultural interventions that improve productivity. The catchment conservation measures also build resilience, enhancing communities' ability to adapt to climate change. Over 40 water funds have been established in 13 countries by The Nature Conservancy. This includes the Upper Tana Nairobi Water Fund launched in 2015, which provides proof of concept for the proposed MWF. This fund was initially capitalised with US$10 million, and further fundraising is ongoing. It has contributed to the improved conservation and management of 40 000 ha of public forest and 78 400 ha of farmland and has increased yields for smallholder farmers by US$3 million per year. It is estimated to have increased water yields and improved water quality for Nairobi, with benefits to power generation and water treatment facilities worth over US$850 000 per year.

3. Mombasa's water supply situation

Mombasa is home to 1.2 million people, making it Kenya's second largest city after Nairobi. Situated along the Western Indian Ocean coastline, it is Kenya's foremost tourist city and the country's main port for the import and export of goods. Up to now, Mombasa has relied entirely on groundwater wellfields and springs for its water supply, most of which are located long distances (up to 220 km) away in Kwale, Kilifi and Taita-Taveta counties. The city is thus part of an extensive bulk water supply network which serves Mombasa and several other urban centers in the region (Figure III), providing water to around two million people. The Baricho Wellfield and Mzima Springs are currently the major sources of water in this water supply system, with a relatively small amount contributed by Marere Springs and Tiwi Wellfield.

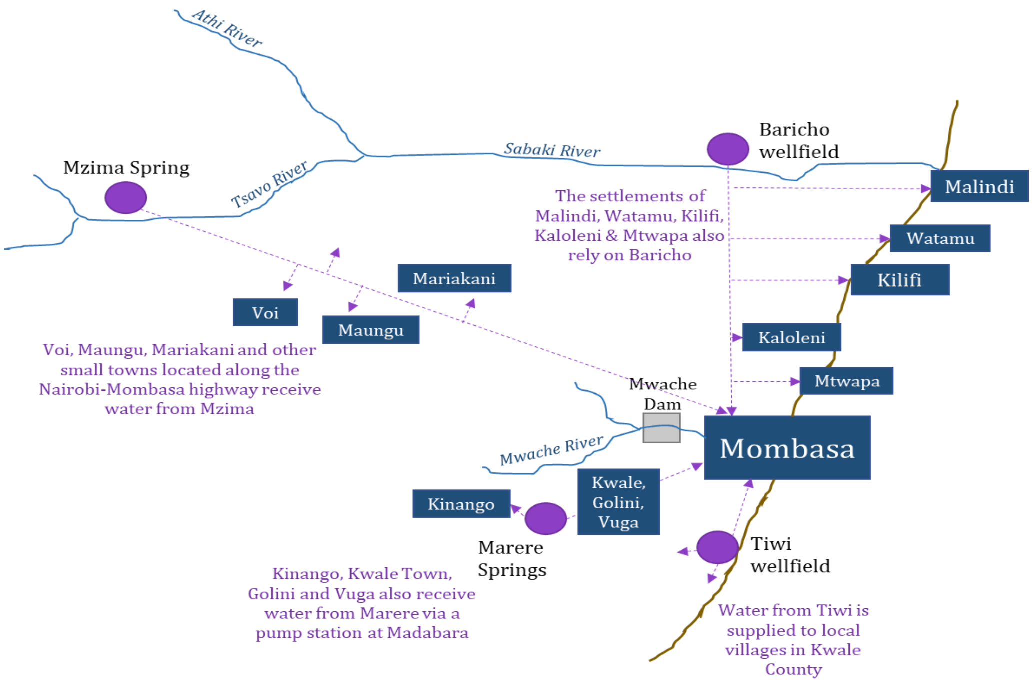


Figure III. Schematic showing water sources for Mombasa and other towns and villages that receive water from these same sources. Note that Mwache Dam is still to be constructed and will supply water primarily to Mombasa.

The bulk water supply system is currently managed by the Coast Water Works Development Agency (CWWDA), a national government agency responsible for managing and maintaining the waterworks and pipelines. Bulk water from the various water sources is sold by the CWWDA to the county water service providers (WSPs). In the case of Mombasa, the WSP is the Mombasa Water Supply & Sanitation Company (MOWASSCO). The county WSPs then sell water on to consumers. County WSPs are also responsible for maintaining water transmission and sewage infrastructure within their areas of jurisdiction. Under Kenya's devolution framework, management of this bulk water system will eventually be handed over to a joint authority which has yet to be formally constituted. This authority should ideally have a mandate to invest in protection and management of its source water areas.

Despite its importance as an economic and tourism hub, Mombasa experiences severe water shortages. Although recent precise figures for Mombasa's total water demand are difficult to find, overall demand is estimated to be around 200 000 m^3/day. This demand from Mombasa alone is greater than the design capacity of the entire bulk water supply system, which is just 148 000 m^3/day. Due to allocations to upstream users, only 46 500 m^3/day is allocated to Mombasa. Furthermore, leakages, breakdowns, over-abstraction upstream and other system challenges mean Mombasa only receives around 35 000 m^3/day on a good day. This is just 17.5% of the 200 000 m^3/day demand estimate for the city. Furthermore, the gap between water demand and existing supplies will only worsen as the population continues to grow. By 2035, Mombasa's demand is projected to increase to about 320 000 m^3/day, while the demand on the whole bulk water system will increase to 530 000 m^3/day. Expansion of the city's water supply is thus an urgent priority.

The shortfall in the city's formal water supply has forced residents and business to rely on private boreholes, wells and water vendors. Drilling boreholes is costly and does not always result in potable water, while water from bowsers is several times more expensive than water provided by MOWASSCO, placing a severe burden on the city's poorer residents. Furthermore, the proliferation of unregulated boreholes has resulted in widespread salinization problems given the city's coastal location. Notably, 94% of borehole water samples taken from across Mombasa's North Coast were found to exceed WHO salinity limits, rendering it unsuitable for drinking without costly treatment. Additionally, Mombasa effectively lacks a sewage system, forcing residents to rely on soakaways. This in turn contaminates borehole water, presenting a serious health risk. Boreholes thus do not provide a satisfactory solution to the city's water supply woes, particularly as water table drawdown and salinization will worsen with continued abstraction. Given this, our stakeholder engagement revealed a strong appetite for a more reliable, public water supply, which could be tapped into to provide support to the MWF. Even major corporate users with existing boreholes indicated they would consider supporting the MWF as a way of securing alternative water supplies for their business activities, given uncertainty around the long-term viability of reliance on boreholes.

Major new infrastructure has been planned to help remedy this situation. This includes new offtake infrastructure and pipelines to increase the supply from Mzima Springs, and the Mwache Dam and treatment works to augment the supply of water to Mombasa and Kwale County. With a planned commissioning date in early 2022, the Mwache Dam is set to become the largest supplier of water to Mombasa in the future, projected to supply 186 000 m^3/day. Expected to take six to eight years to complete, the dam will exceed the current supply capacity of the entire bulk water system, enabling the whole system to meet projected water demands in 2035. Meanwhile, the expansion of the Mzima Springs infrastructure is projected to increase abstraction from 35 000 m^3/day to 95 000 m^3/day, of which 50 050 m^3/day will be allocated to Mombasa. However, the future sustainability of both these water sources is threatened by land use practices.

4. Recent advances towards improving water security

The World Bank "Kenya Water Security and Climate Resilience Project - Phase 2 (Coast Region)" (KWSCRP-2) includes the construction of Mwache Dam and other infrastructure, also includes components for Mwache catchment management, sustainable livelihoods and sanitation.

The catchment management component has undertaken studies of catchment erosion (the Physiographic Study, 2017), of local livelihoods and intervention options (the Options Study, 2017), and is assisting Water Resource User Associations (WRUAs) with the development of Sub-catchment Management Plans. The Physiographic Study recommended that soil conservation activities be carried out over 26 000 ha, at an estimated total cost of $30 million. The current project has a limited budget for this ($5000) and had treated 780 ha by 2019, out of a planned total of 2000 ha.

A Detailed Design Report (2018) for the Mwache Dam explains that without additional intervention, the lifespan of the Mwache Dam would be only 20 years, and that two large sediment check dams are needed to extend its lifespan to 100 years. However, the check dams need to be fully cleared of their annual accumulation, at an estimated annual cost of $8 million that is not covered by the project budget.

The studies that have been carried out under KWSCRP-2 have provided significant insight into the unfolding water security situation. While the infrastructure projects are set to alleviate water security issues, it is clear from the Detailed Design Report, that the project still carries significant risk, with very large sums of money needed to maintain the required level of water delivery from the main asset being developed – the Mwache Dam.

While much work has been done towards determining what interventions are needed to reduce sedimentation of Mwache Dam and how to finance them, some details are still sketchy, and further work is required to synthesise and build on this body of work to make a sound business case and develop a workable and sustainable model for implementation. In addition, the recent work proposing a PES intervention for the Mzima Springs recharge area, needs to be taken into consideration for possible inclusion in the proposed Water Fund.

PART II. NATURE-BASED SOLUTIONS FOR WATER SECURITY

5. Proposed interventions for the Mwache Dam catchment

Located mostly in Kwale County, the Mwache Dam catchment covers an area of 3560 km^2, with the dam site situated about 20 km west of the city of Mombasa. The catchment is generally semi-arid with rainfall increasing towards the coast. Overall, the catchment is characterized by high poverty levels and limited livelihood opportunities. Farming is the main livelihood activity, with most households in the central and eastern parts of the catchment practicing a mixture of crop cultivation and livestock rearing. In the more sparsely populated western parts of the catchment, livestock farming and wildlife conservation on group ranches are the dominant activities. Charcoal production and sand mining have become common in recent years, particularly closer to the urban centres and main roads.

Land use practices, sand mining and fuelwood harvesting in the catchment area present a serious threat to the lifespan and potential water yield of the dam. These activities increase soil erosion and sedimentation, which in turn elevate rates of sediment accumulation in the dam, reducing its capacity. These activities also have a negative impact on water quality, which significantly increase water treatment costs. The costs of sediment clearing, and water treatment will ultimately fall on consumers, as these activities will increase the cost of water supplied from the dam.

To mitigate the threat of sedimentation, two large check dams have been planned to trap sediments upstream of the Mwache Dam. These should significantly reduce the amount of sediment entering the main dam, though there will be some overflow as well as inputs from the remainder of the catchment. At current rates of erosion and sedimentation the lifespan of the dam could be reduced to as little as 20 years. Extending the lifespan of the dam will only be possible if sediment is cleared each year from both check dams. If not, the check dams will themselves rapidly fill up with sediment and no longer serve to protect the main dam. Clearing sediment from these check dams will require significant amounts of labour and equipment, and costs could be as high as US$8 million per year according to the sediment management plan. While funding for the check dam construction and some catchment rehabilitation activities has been secured through the Kenya Water Security and Climate Resilience Project - Phase 2 (KWSCRP-2), it is not clear who will be responsible for clearing the check dams and how this will be funded. Given the high costs involved in clearing the check dams, efforts to reduce sediment export from the catchment could result in significant avoided sediment removal costs. Furthermore, increased protection of the vegetation and soils of the catchment area will be essential to avoiding elevated water treatment costs.

Therefore, in the Mwache Dam catchment, the focus of nature-based solutions would be on reducing soil erosion given this is the primary threat to sustainability. This will help to mitigate the threat of sedimentation to water quality and the future water storage capacity of the dam. A key premise of this approach is that addressing soil erosion at source will be cheaper than removing sediment once it reaches the check dams or main reservoir. This will also reduce water treatment costs by reducing loads of suspended solids and other pollutants. The proposed solutions also have the potential to improve livelihoods through increased agricultural productivity and expanded opportunities for the generation of income through nature-based tourism. Some of the proposed interventions will also contribute to carbon sequestration and biodiversity conservation.

Based on the likely effectiveness of a range of potential measures, the biophysical characteristics of the catchment and land use activities, and the likely acceptability of different options under the socio-economic and institutional context, the following combination of environmental management measures is proposed:

i. Active rehabilitation, which includes planting appropriate trees and grass in badly degraded riparian and roadside areas and restoring tree cover in deforested areas;

ii. Soil erosion control (SEC) interventions on farmland, including cover crops, reduced and no tillage approaches, agroforestry, and terracing, with different combinations of interventions proposed depending on slope;

iii. Sustainable natural resource management, which includes sustainable rangeland management, sustainable use of fuelwood, and the managed recovery of degraded areas; and

iv. Conservation of important natural areas, which includes protection of all riparian zones and the establishment of community wildlife conservation areas (i.e., potential expansion of conservancy areas) in larger blocks of remaining natural vegetation that are not currently protected.

Suitable areas for the selected environmental management measures were mapped in geographic information systems (GIS) software using a combination of datasets, including areas where deforestation and land degradation have occurred (Table I). However, the return on investment (ROI) of these interventions varies across the catchment due to variations in both costs and benefits. We therefore identified priority areas for the interventions based on ROI (sedimentation avoided per dollar spent). Prioritising intervention areas in terms of ROI provides the most cost-effective plan for any given budget. Given that the budget constraint was unknown, we included all areas up to the point of inflection where the ROI starts to diminish more rapidly. Beyond this point, the ROI for additional intervention areas becomes increasingly less likely to compete with the ROI for grey infrastructure interventions.

Estimating the spatial variation in ROI involved modelling the percentage change in sediment export from the landscape after the implementation of the proposed interventions across all potentially suitable areas using the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) Sediment Delivery Ratio (SDR) model. Resulting changes in sediment export to the dams in physical terms was based on previous studies which used SWAT. The prioritization of sites for intervention was carried out using the Restoration Opportunities Optimization Tool (ROOT).

Table I: Summary of criteria used to map potential areas for the proposed interventions

Intervention	Criteria
Riparian rehabilitation	Riparian areas (within 30 m of watercourses) under non-natural land cover and/or with tree cover loss and/or with a decline in NDVI
Active rehabilitation (non-riparian areas)	Non-riparian areas still under natural land cover which have experienced a decline in tree cover
SEC1 on cultivated land	Cultivated areas with slope <5%
SEC2 on cultivated land	Cultivated areas with slope 5-9%
SEC3 on cultivated land	Cultivated areas with slope >9%
Sustainable natural resource management	Non-cropland areas exhibiting a decline in NDVI (*i.e.* degradation)
Riparian protection	Riparian areas (within 30 m of watercourses) that do not meet criteria for rehabilitation
Community conservation areas	Currently unprotected areas with relatively contiguous coverage of shrubland and/or forest

The proposed portfolio of interventions in the Mwache Dam catchment were estimated to cover just over 43 000 ha with a total cost (expressed in present value terms) of US$ 31.3 million (Table II).

The sustainable natural resource management and conservation intervention includes costs for the planning and implementation of a PES-type scheme in the western group ranch areas of the Mwache Dam catchment. While this would take the lion's share of the budget due to the size of the area over which it would be implemented, it has the lowest per hectare cost compared to the other interventions.

Table II. The areal extent and cost (expressed in present value terms; 2021 US$ millions, 6.52% discount rate, 30 years) of proposed interventions in the Mwache Dam catchment

Intervention	Area (ha)	Cost (US$ million)
Restoration of riparian and other forest cover	585	1.3
Soil conservation measures on cultivated land	12 444	11.2
Sustainable natural resource management and conservation	30 231	18.8
Total		**31.3**

6. Proposed interventions in the Mzima springs recharge area

The Mzima Springs are fed by water from the Chyulu Hills Volcanic Aquifer. The aquifer's recharge area is around 2000 km^2, most of which is in Makueni County. The cloud forests of Chyulu Hills play a vital role in capturing rainfall and condensation (from mist) that infiltrates into the underground aquifer. The Chyulu Hills National Park covers the eastern portion of the hills which adjoins the Tsavo West National Park to the southwest. Pastoralism is the dominant livelihood activity on the western side of the Chyulu Hills, making way for crop production in some parts. On the eastern side, small-scale subsistence agriculture dominates. This area also includes the main Nairobi-Mombasa highway and its associated towns and businesses.

Water supply from the Mzima Springs is threatened by deforestation. Continued loss in forest cover is expected to lead to a significant decline in rainwater infiltration rates and a reduction in the amount of water that is discharged from the aquifer at the springs. Therefore, measures to halt and reverse the loss of forest cover are essential to protect the significant infrastructure investments being undertaken and to safeguard future water security for the region.

Therefore, in the Mzima Springs recharge area, the focus of nature-based solutions would be on reducing deforestation and rangeland degradation in the Chyulu Hills, thereby aiming to restore and secure the groundwater recharge capacity of the area and avoid future declines in the amount of water that can be extracted from the Mzima Springs.

While efforts have already been made to address forest and rangeland degradation problems in the recharge area through the establishment of a REDD+ Project by the Chyulu Hills Conservation Trust in 2013, further investment is needed to ensure water security. While the project has already generated $12 million from the sale of carbon credits, and is expected to generate another $30 million in its next phase, financial analysis suggests that further income streams are needed to achieve the level of conservation required. The addition of payments for hydrological services to the revenue stream (which also includes ecotourism, philanthropy and government support) would help to achieve this, as well as helping to smooth funding flows.

The MWF could contribute to the successful protection of the geohydrological functioning of the recharge area through transfers to the Chyulu Hills Conservation Trust. The Project Area covers about 4100 km^2, of which the Chyulu Hills Water Tower makes up a quarter. This would help the Trust to provide a steadier flow of payments and support to communities in return for conservation action. Based on GNIplus (2021), additional funding of US$6.3 million per year is needed to meet the REDD+ objectives of halting and partially reversing deforestation in the Chyulu Hills, amounting to US$72 million (in present value terms) over a 30-year period.

PART III. MAKING THE BUSINESS CASE FOR MOMBASA WATER FUND

7. Impacts on water supply (yield and quality)

Modelling of the impacts of the proposed MWF interventions on water yield and quality in the Mwache Dam was performed using the Water Evaluation and Planning (WEAP) tool. WEAP operates on the basic principle of water balance and can be applied to catchment and agricultural system. It can simulate a broad range of natural and engineered components of these systems, including rainfall runoff, baseflow, and groundwater recharge from precipitation; sectoral demand analyses; water conservation; water rights and allocation priorities, reservoir operations; hydropower generation; pollution tracking and water quality; vulnerability assessments; and ecosystem requirements. Recently, WEAP expanded with a module to evaluate erosion and sediment transport in rivers. This erosion plugin uses the same concepts and equations as used in the SWAT model (MUSLE-based).

The WEAP model required various data inputs. This included climate data, which was sourced from the Global Surface Summary of the Day (GSOD) database. These data were interpolated using the ERA-5 Land reanalysis dataset. Reanalysis also produces data that goes several decades back in time, providing an accurate description of the climate of the past. This process revealed substantial inter-annual variation in precipitation in the catchment. A clear trend cannot be observed, although the most recent years are somewhat wetter. A more long-term trend seems to indicate that the last 10 on average are somewhat dryer compared to overall average rainfall for the past 40 years, by about 5%. In addition to climate data, the WEAP model used a global digital elevation model (DEM), a land cover layer, data on soil conductivity and water holding capacity and streamflow data. The latter is particularly scarce for the Mwache River. Information on the storage capacity, storage-elevation curve, minimum drawdown levels and other data on the hydrology of the Mwache Dam was taken from the design report for the dam.

The WEAP model estimated total catchment runoff as the sum of three flows: fast runoff, interflow and baseflow. Fast runoff is the fraction of the rainfall that does not enter the soil, but flows directly overland into the streams and rivers. Interflow is the amount of precipitation that flows through the soil, eventually ending up in streams and rivers at a slower rate than fast runoff. Finally, base flow is the amount of precipitation that flows through the soil layer into the groundwater and ends up eventually in streams and rivers through groundwater discharge. A small fraction of the precipitation in the Mwache Dam catchment ends up in streams and rivers as the majority of the water is consumed by the vegetation. Areas where surface runoff is high might be considered as potentially suitable areas for interventions. At the same time restoring degraded areas will increase actual evapotranspiration which might lead, if no other measures are taken, to less water ending up in a reservoir. Obviously, in many cases this somewhat negative impact is outweighed by the positive effects of flow regulation, lower flood risk and lower erosion rates. Overall total catchment runoff from the current landscape was estimated to be around 270 MCM/year. Fast surface runoff, which is the main trigger of water erosion, accounts for around 20% of this on average. However, the contribution of fast runoff varies significantly across the catchment.

There is hardly any quantitative information on water quality and wastewater produced in the Mwache Dam catchment. In the absence of reliable data general figures provided by FAO are included in the WEAP model. Based on the FAO publication it was assumed that a value of 6 mg/l phosphorous would be in the runoff water that flows into the streams, given the lack of domestic sanitation waste management facilities in the catchment. The total amount of phosphorous (as P) generated in the catchment is on average 152,000 kg per year. Total outflow of the catchment is on average 76,000 kg showing the natural cleaning capacity of the streams by various chemical processes.

The WEAP erosion plugin was used to assess the erosion rates on a daily basis. For consistency with the InVEST SDR modelling, the same parameters were used in the WEAP model for the cover factor (C factor) and supporting practice (P) of the various land cover categories in the catchment. The results indicate that total annual erosion by water can be as low as 0.07 million tons per year in very dry years and up to 0.75 million tons per year in wet years. These differences can be attributed to the rainfall and especially to the peak rainfall intensity within a day. One large rainfall event can generate as much erosion as during the rest of the month or even year. As expected, crops, degraded land covers and "built-up" areas (which includes bare soils) generate most of the erosion in terms of tons per hectare.

The above paragraphs describe the baseline hydrological situation for the Mwache Dam catchment under current land cover. The next step thus involved defining future scenarios and evaluating the changes in hydrology that would occur with each of these. This included a business as usual (BAU) scenario, where no catchment conservation interventions are implemented nor are any check dams built. The second scenario is termed the World Bank (WB) interventions scenario, which involves construction of the check dams to trap sediment upstream of the main reservoir, as well as conducting rehabilitation activities across 2 000 ha of the catchment. These activities include afforestation and reforestation activities, constructing terraces and gabions to regenerate vegetation and control erosion, and marking and pegging riparian areas where vegetation needs to regenerate. The next two scenarios were based on the selection and mapping of interventions undertaken as part of this design study. Hence, the third scenario evaluates the hydrological impacts of carrying out priority interventions as proposed which focuses on intervening in areas which generate the greatest return on investment in terms of sediment saving. The fourth scenario evaluates the impact of carrying out the proposed interventions to their maximum potential extent i.e. the MWF full extent scenario. For both MWF intervention scenarios, we assumed that sediment check dams would be constructed, as per the World Bank scenario. This is because check dam construction is planned as part of the dam design. Hence, the interventions proposed under the MWF can be thought of as complementary to check dam construction. They both also involve intervening over a larger portion of the catchment than the World Bank scenario does.

Relative to the BAU scenario, the WEAP model predicted erosion is only reduced by 3-4% under the World Bank scenario through the regeneration of some parts of the catchment. The MWF scenarios both reduce erosion quite substantially, such that mean erosion only rises above 1 ton per hectare during wet years. This is reflected in the decline in erosive runoff with the various intervention scenarios. Under the WB scenario, erosive runoff is reduced by 1.7% relative to BAU, while it declines by around 18.1% and 30.6% under the priority and full extent scenarios, respectively. Notably, total runoff is also lower under the intervention scenarios. However, the negative reduction in total water outflow by regenerating catchments is in most cases far outweighed by the gains in other processes (less erosion, more green vegetation, lower flood risks, etc).

In terms of water quality, the MWF scenarios can significantly reduce total suspended solids (TSS), which are of relevance for drinking water treatment costs. Removal of sediments in drinking water treatment facilities can be quite expensive as large amount of chemicals used for coagulation-flocculation (often alum and iron) have to be used. A threshold value of 0.5 g/l is widely used as an acceptable limit for TSS in drinking water. This threshold is predicted to be exceeded in around 30% of the days under the BAU and WB scenarios. Meanwhile, exceedance of the TSS safety threshold only occurs in around 10% of days under both MWF interventions scenarios, which should significantly reduce water treatment costs.

8. Economic analysis

The proposed nature-based solutions in the Mwache Dam catchment and Mzima Springs recharge area could collectively lead to avoided water supply costs amounting to over US$6 million per year.

Interventions in the Mwache Dam catchment are expected to reduce the costs of managing sedimentation of the check dams, maintain higher dam yields and reduce water treatment costs, as follows:

- Modelling carried out using the InVEST TDR tool suggests that the proposed Mwache Dam catchment interventions could reduce sediment export by at least 16% relative to the business-as-usual (BAU) situation. A major benefit of this would be the reduction in the costs of sediment clearing from check dams. Based on the estimated sedimentation rates and annual costs of sediment clearing from the check dams in the design report, this suggests that the proposed soil conservation measures could save approximately US$1.23 million per year in bulk water supply system management costs.

- In addition, the Water Evaluation and Planning (WEAP) hydrological modelling tool was used to estimate how the conservation measures would impact the yield of the Mwache Dam, taking into account changes in flows in the catchment and the residual sedimentation of the Mwache Dam (which is not entirely protected by check dams). This suggested that yield would increase by 1.1% relative to the BAU scenario. In other words, yield will decline more slowly over time, saving on having to make up this difference from the next best alternative, which is likely desalination. Thus, the interventions could result in additional water supply cost reductions of US$0.75 million per year by 2030.
- The WEAP model was also used to estimate how the interventions would impact on the quality of water entering the dam, notably the loads of phosphorous and total suspended solids (TSS). A reduction in suspended sediments and associated nutrient inputs decreases the need for flocculation, filtration and backwashing in the water treatment process. Based on an assumed daily water treatment capacity of 140,000 m^3 for the proposed treatment plant, which is the reported capacity of the proposed water treatment works attached to Mwache Dam, the reduction in TSS and phosphorous resulting from the proposed catchment management interventions is expected to avoid annual water treatment costs of US$0.85 million. However, these are approximate estimates, since water quality is not closely monitored, their impact on raw water quality depends on dam conditions, and the dam and water treatment plants are yet to be built.

Interventions in Mzima Springs recharge area are expected to avoid the reduction in yield from the springs, saving on grey infrastructure costs needed to make up the shortfall. Estimating the benefit of reducing deforestation and degradation was based on hydrological modelling using WaterWorld and an accompanying risk assessment carried out for a recent feasibility study for implementing payments for hydrological services in the Chyulu Hills area which considered how change in land use and management in the Mzima Spring recharge area might affect water supply at the spring. The study found that several risk factors have a high likelihood of occurrence and could have severe and unmitigable impacts on water supply if deforestation of the cloud forests continue at current rates, but these effects could not be accurately quantified using available data. Therefore, based on expert opinion, it was conservatively assumed that under a BAU scenario, yields would be reduced by at least 25% relative to an intervention scenario. The value of this 25% increase in water supply compared to the BAU scenario which would be brought about by augmenting existing efforts to incentivize conservation action in the Mzima Springs recharge area was estimated to be at least US$3.26 million per year. This assumes that the Chyulu Hills REDD+ project operational model is also strengthened.

There are a number of additional benefits that could arise from the MWF interventions, through changes in ecosystem condition and the supply of ecosystem services, other than those that are directly associated with formal water supply. These co-benefits include tangible livelihood benefits obtained by rural households from increased crop production, income and employment benefits from tourism and recreational activities, and avoided climate change costs to local and global society through retention of intact natural ecosystems.

Rural populations in the study area rely primarily on agriculture for their livelihoods. However, most of the Mwache Dam catchment is dry with low agricultural potential and the area is prone to periodic food shortages. Maize is the staple food crop grown by most farmers. Maize yields are significantly lower here than in other (wetter) parts of Kenya. Total crop production from the catchment is estimated to be about 21 700 tonnes per year, with an estimated value of US$11.5 million per year. If it is conservatively assumed that implementation of on-farm soil conservation interventions, which would reduce soil losses and improve water retention, would increase yields in the project sites by

25%, this would result in an increase in crop production value of US$1.1 million per year relative to a BAU scenario.

Nature-based tourism is the backbone of the tourism industry in Kenya and is a key contributor to socio-economic development. In the Chyulu Hills, ecotourism is a key income-generating activity, and the Mzima Springs site is also a major tourist attraction in the region. There is limited ecotourism in the upper Mwache Dam catchment where wildlife conservancies have been established in the corridor area between Tsavo West and Tsavo East National Parks. This has seen the development of several small tourist lodges and community tourism projects. The rest of the catchment, outside of these wildlife conservancies is less suited to ecotourism.

We estimated that in 2019, nature-based tourism in Mwache Dam catchment and the Mzima Springs recharge area contributed US$8.8 million and US$11.7 million to tourism expenditure, together making up 1.2% of the total attraction-based tourism spend in the country. The per hectare spend was highest in the protected areas, with values as high as US$105/ha in Tsavo West and averaging just US$17/ha outside of protected areas.

Restoration, improved protection and establishment of community wildlife conservation areas should result in gains in wildlife habitat, with these areas having an opportunity to increase in value over time to be more in line with values currently seen in the surrounding conservancies and protected areas. In the Mwache Dam catchment, in-country tourism spending was expected to increase by about US$2.84 million annually by the end of the 30-yr analysis period compared to the BAU scenario. The gains were estimated to be slightly higher in the Mzima Springs recharge area, at US$3.07 million per year by 2050 when compared to the BAU.

Natural systems play a critical role in the global carbon cycle. Based on global datasets derived from satellite data, it was estimated that approximately 17.1 million tonnes of carbon (tC) are stored within the vegetation and soils of the Mwache Dam catchment. Under the current trajectory, a total of approximately 382 600 tC could be lost over the 30-yr analysis period. The analysed nature-based solutions not only would avoid this BAU degradation of carbon stocks but would increase current carbon sequestration and storage through agroforestry, farmer managed natural regeneration and active restoration, resulting in net gains of 467 000 tC compared to the BAU scenario. This would result in avoided climate-related damage costs of about US$22 million at a global scale, and some US$0.03 million to Kenya. Furthermore, the establishment of a community wildlife conservation area in the central northern part of the catchment would link the adjacent Tsavo East National Park and the existing Shirango Conservancy to other Tsavo Region conservancies and the Wildlife Works Kasigau Corridor REDD+ Project ranches in the west. This conservation area spans approximately 20 000 ha and could potentially, through the Kasigau Corridor REDD+ Project, generate earnings of US$0.2 million per year through the sale of carbon credits.

Based on information extracted from the Chyulu Hills PES feasibility study, it was estimated that approximately 5.3 million tC are stored within the forest and grassland areas of the Chyulu Hills. We estimated 8.1 million tC could be gained relative to a BAU scenario through sustainable forest management, worth US$416 million at a global scale, and US$0.6 million to Kenya in avoided climate-related damage costs. In addition to the avoided climate related damage costs, the residual gains in carbon relative to the BAU scenario, as a result of halting deforestation and ensuring afforestation of some 58 000 ha through the water PES scheme, could be worth about US$2.3 million per year at current market prices for carbon.

The costs and benefits of the proposed MWF restoration and conservation interventions described above were analyzed over a time period of 30 years at a social discount rate of 6.52% to determine their potential overall net benefit and the return on investment (ROI, net welfare gains per US$ invested). The robustness of these figures was also tested using sensitivity analysis.

Contributions to the Chyulu Hills PES Scheme through the MWF to ensure protection of the cloud forests could generate benefits in the order of US$92 million over the 30-year time frame (Table III). This represents a return of some US$1.30 in benefits for every dollar spent. However, the benefits could be far greater than this, as the Chyulu Hills also support significant biodiversity and wilderness areas, which are valued both by Kenyan citizens and by global society, and which contribute to Kenya's biodiversity conservation commitments. There are a great number of people, including many who may never visit the area, who would have a positive willingness to pay for conservation of this landscape. These non-use values could greatly exceed the tourism value of this area.

Investments in the Mwache Dam catchment are expected to have even better returns. Here, a US$31 million investment in restoration interventions is expected to return at least US$65 million in economic benefits over the 30-year timeframe (Table III). In other words, every US$1 invested by the Water Fund is expected to generate at least US$2.10 of included benefits to stakeholders. Again, in addition to the water security and tangible co-benefits included in the calculations, this would also come with some biodiversity benefits, in that improved conservation in the upper part of the catchment would increase wildlife habitat and the connectivity of conservation areas in the region.

Taken together, the overall investment costs would amount to US$104 million, with returns of US$157 million, resulting in a net present value of US$53 million and an ROI of 1.5 (Table III). Figure IV shows how the benefits, costs and net annual benefits are anticipated to be realized over time for the Mwache Dam catchment and Mzima Springs recharge area.

Table III. Present value of the costs of interventions and value of ecosystem service benefits for Mwache Dam catchment and Mzima Springs recharge area (2021 US$ millions, 6.52% discount rate, 30 years).

	Present value (US$ millions)		
	Mwache Dam catchment	**Mzima Springs recharge area**	**Combined**
Costs			
Restoration of riparian and other forest cover	1.3		1.3
Soil conservation measures on cultivated land	11.2		11.2
Sustainable natural resource management and conservation	18.8		18.8
Community forest management: Chyulu Hills Water PES	-	72.5	72.5
Total present value of costs	**31.3**	**72.5**	**103.8**
Benefits: Mwache Dam catchment			
Impacts on water yield	6.9	-	6.9
Savings on check dam dredging	11.9	-	11.9
Avoided water treatment costs	8.2	-	8.2
Production gains from agriculture interventions	12.9	-	12.9
Carbon gains*	2.3	-	2.3
Increase in tourism and recreation opportunities	23.3	-	23.3
Benefits: Mzima Springs recharge area			
Impacts on water yield	-	31.3	31.3
Carbon gains*	-	32.5	32.5
Increase in tourism and recreation opportunities	-	27.8	27.8
Total present value of benefits	**65.4**	**91.6**	**157.0**
Net Present Value	**34.1**	**19.1**	**53.2**
ROI	**2.1**	**1.3**	**1.5**

* These results include the market value of carbon (if sold through the Chyulu Hills REDD+ Project or the Wildlife Works Kasigau Corridor REDD+ Project) as well as the avoided climate-related damage costs to Kenya.

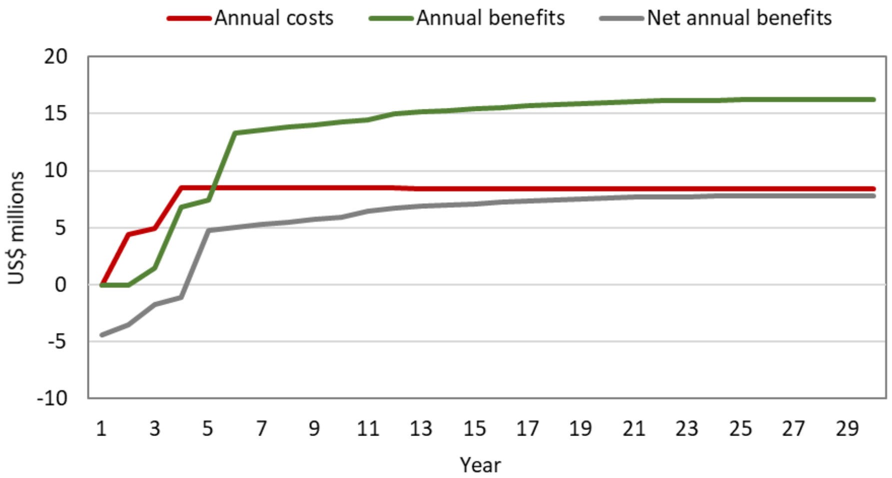


Figure IV. Total annual benefits and costs over time for the extended analysis of the Mwache Dam catchment and Mzima Springs recharge area (2021 US$ millions, 30 years).

Under varying assumptions of costs and benefits and timing and discount rates, the results of the analysis remain favourable, but only just in some cases. Changing the assumption around agricultural yields to be more conservative reduced the ROI to 1.4 and removing community conservation areas increased the ROI slightly to 1.5. The ROI for the Mwache Dam catchment remains positive at 1.3 even when tourism benefits are excluded from the analysis. However, while the net benefits remain positive under varying assumptions, the overall viability of the MWF is sensitive to changes in the timing of benefits as well as in terms of the costs of interventions. Increasing costs and decreasing the benefits by 15% dropped the ROI to 1.1 and delaying restoration benefits by a further three years dropped it to 1.2, with a net present value of US$9.6 million and US$19.1 million, respectively.

In addition to security in water supply and water quality, expanded forest protection, active restoration of degraded forest areas and rangelands, and community support for sustainable agriculture in the eastern community areas and improved grazing and rangeland management in the pastoralist areas in the Chyulu Hills could bring wider benefits. These include nature-based tourism, climate change resilience, job creation, opportunities for women and most importantly, avoiding the irreversible loss of the unique and valuable biodiversity of this area. While the overall viability of the MWF could be sensitive to changes in the timing of benefits as well as in terms of the costs of interventions, the sensitivity analysis shows that even under these conditions, economic viability can still be maintained.

The following key results demonstrate the importance of catchment restoration and conservation and the feasibility of establishing the MWF. Compared to a business-as-usual scenario, investing in catchment ecological infrastructure would yield the following returns:

- The amount of sediments entering the rivers of the Mwache Dam catchment would be reduced by approximately 16% (109 000 tonnes), with an annual cost saving in terms of dredging sediment check dams of US$1.23 million per year;
- A 1% loss in average annual water yield from the Mwache Dam catchment could be prevented, which translates into avoided costs of US$0.38 million per year for the first five years, US$0.42 million per year for the next five years, and US$0.75 million per year after that;
- Losses of at least 25% in water yield from the Mzima Springs could be prevented, translating into avoided costs of at least US$3.26 million per year;
- The amount of phosphorous and TSS entering the rivers of the Mwache Dam catchment could be reduced by 70% and 50%, respectively, with annual avoided water treatment costs of around US$0.86 million per year;

- Agricultural interventions implemented on cultivated land could increase agricultural productivity through improved crop yields, generating increases in annual returns of US$1.07 million per year to farming households;
- Carbon stored in the study area would be 9.1 million tonnes higher over the 30-yr study horizon, avoiding estimated annual climate change damages of US$640 000 to Kenya and US$438 million at a global level, with a current carbon market value of US$2.50 million per year;
- Increased tourism related spending across the study area could amount to US$5.90 million annually by 2050; and
- Nature-based solutions will have a positive impact on the pollination of crops in nearby fields by insect pollinators that are supported by natural habitats, cultural values derived from improved community forest management in Kwale county, nutritious (and income earning) fruits from fruit trees planted in agroforestry systems, human and livestock health benefits associated with the cooling services provided by agroforestry systems, and the potential health benefits as a result of reduced coliform loadings into waterways through rehabilitation of riparian buffers.

PART IV. STAKEHOLDERS, GOVERNANCE AND INSTITUTIONAL CONTEXT

9. Policy, legal and institutional landscape

As part of the assessment, a comprehensive review of the policy, legislative and institutional framework around water resource management and catchment conservation was conducted. This was used to identify opportunities and barriers to the MWF arising from the current policy, legislative and institutional landscape.

While water funds are not explicitly anchored in any formal policy or legislative instruments in Kenya, this review revealed that the concept is nevertheless compatible with various existing frameworks and helps to realise goals and visions for conservation and water resource management enshrined in various policies and acts. For example, the MWF is in line with several the objectives identified in the National Water Policy, including protecting and securing the sustainable supply of water resources and pursuing suitable financing systems for water resource management, including emphasis on the role of public-private partnerships (PPP). Meanwhile, objectives of the National Environment Policy include promoting partnerships in the protection and sustainable management of the environment and natural resources, and promoting the use of innovative conservation approaches such as conservation incentives, including payments for ecosystem services (PES). The Land Reclamation Policy seeks to increase public investment in addressing land degradation to at least 1% of national budget, a commitment which the proposed interventions under the MWF can help to address. It also calls for the creation of enabling environments for increased private investment in land rehabilitation, primarily through PPPs, and to promote extension and training services.

The MWF can also help realise various Kenyan strategies and plans. For example, the National Environment Action Plan calls for several strategies to improve environmental stewardship, including designing and implementing projects around the restoration of degraded catchments and developing comprehensive river basin management programs focusing on catchment rehabilitation to stem sediment yields. Similarly, the activities proposed under the MWF meet several of the strategic focal areas in the Athi Integrated Water Resources Management and Development Plan for addressing water-related issues in the Athi Basin. Most notably, this plan emphasized the importance of innovative financing in the implementation of the proposed catchment management interventions and for strengthened coordination between different county governments and relevant governing bodies and institutions. These provisions imply an innovative resource mobilization strategy which recognizes the roles of the county governments, water sector institutions and the private sector in catchment protection and conservation is urgently required.

Legislative grounding for the MWF can be found in acts such as the Environmental Management and Control Act. Among other things, this act calls for the protection and sustainable use of water resources and catchment areas, including provision for government agencies to issue guidelines and prescribe measures to secure water catchment areas. It also provides for the establishment of user fees to ensure those who use environmental resources pay the proper value for this utilization. The County Government Act allows county governments to enter into partnerships with any public or private organization for any work, service or function. This provides another entry point for anchoring the water fund, which aims to bring together public and private actors to secure hydrological services. This provision for PPPs has been integrated into the acts of the individual counties in the Coast region. For example, the Mombasa County Water and Sewerage Services Act allows for MOWASSCO to pursue PPP options for the development of water supply infrastructure. The Kwale County Water and Sanitation Services Act has a number of provisions which are in line with the proposed activities of the MWF, including the promotion of water catchment conservation and soil and water conservation. It also has provisions for the country WSP to enter into PPPs in order to effectively carry out its functions. The Kenya Water Towers Bill is of relevance to the Mzima Springs, as the Chyulu Hills source area for these springs has been listed as a water tower. At a high level, the Kenyan Constitution allows for counties to develop institutional arrangements with other counties or the national government on inter-jurisdictional issues of common concern. This is important for the MWF, given the cross-county nature of the Coast bulk water supply system. Once again, the MWF could provide an institutional mechanism for aiding cooperation among counties on water-related issues.

The review also revealed a complex institutional landscape surrounding water resources in the Coast region which the MWF will have to grapple with. At the same time, the fund can play a valuable role in helping to coordinate the actions of the various government actors in fulfilling their constitutional mandates. The institutional landscape surrounding water resource management and provision can be through of as three-tiered - the first tier bearing the responsibility of policy formulation, the second bearing the responsibility for supervision and coordination of policy implementation, and the third having responsibility for implementation, monitoring and enforcement. Policy formulation and regulation around water remains largely a national government mandate. The Ministry of Water and Sanitation and Irrigation is the institution responsible for policy formulation, the development of legislation, planning and resource mobilization, among other functions. Regulating the management and use of water resources is done through the Water Resources Authority (WRA), which functions as an agent of the national government. The Water Services Regulatory Board (WASREB) is another key national government body, mandated to protect the rights of consumers. Among other functions, it sets and approves water tariffs, licenses water service providers (WSPs), and monitors compliance with national standards for water provisioning and licensing conditions. Notably when setting the tariffs, WASREB allows WSPs a component to cover activities undertaken to ensure conservation of water resources, which provides a potential source of revenue to support activities proposed under the MWF.

For management of water resources at more local levels, the Water Act provides for the WRA to be assisted by Basin Water Resources Committees (BWRCs) and Water Resource User Associations (WRUAs). The BWRCs are mandated to formulate basin area water resources management strategies in consultation with the WRA and county governments whose territories lie within the basin. They are meant to be multi-stakeholder bodies containing representatives from the MoWSI, county government, local farmers or pastoralists, NGOs and the private sector. The WRUAs are established at the sub-basin level to promote cooperative governance and address water-related conflicts. They are community-based voluntary organizations which may be contracted by BWRCs and WRA as agents to perform certain duties in water resource management. However, WRUAs' ability to promote catchment conservation and ensure equitable water allocation is challenged by limited financial and technical capacity. In an effort to address this, the WRA and Coast Development Authority (CDA) have been active in increasing the capacity of WRUAs in the Mwache Dam catchment, including assisting them with the development of sub-catchment management plans (SCMPs). These include measures to promote sustainable land management and secure riparian areas within each WRUA's sub-catchment.

The Coast Water Works Development Agency (CWWDA) develops and operates the various national public waterworks located in the Coast Region and sells bulk water from these to the county WSPs. They are also responsible for managing the bulk water transfer infrastructure in the region, such as the pipeline from Mzima Springs to Mombasa. The Water Act provides for the handing over of national public waterworks assets to county governments, or joint county authorities in the case of cross-county water supply networks such as the Coast bulk water system. However, development of the joint county authority is still ongoing, meaning CWWDA remains responsible for managing the waterworks and bulk transfer infrastructure within the region, despite the constitutional provisions for the transfer of water service provision to county governments. Once it does come to fruition, the joint county authority will be an obvious entry point for anchoring the MWF. The Coast Development Authority (CDA) is another relevant regional-level institution. While its mandate does not focus specifically on water, it carries out regional development projects which include efforts to improve water supply. In this regard, it is a key implementing agent for the Mwache Dam project. The CDA has already been heavily involved in developing the capacity of WRUAs in the Mwache Dam catchment in partnership with the WRA, and undertaking sustainable land management interventions on farmland such as terracing and tree planting. It has also worked with the WRA in protecting and restoring riparian areas in the catchment.

Finally, the county water supply companies are responsible for maintaining water and sanitation infrastructure within their areas of jurisdiction and selling water to consumers. As noted earlier, the county WSPs can apply to WASREB for an environmental conservation component to be integrated into their tariffs, provided that the proposed activities are sufficiently documented. The county governments are also mandated to implement national government policies on environmental and water resource management, highlighting that they also have a tole to play in catchment conservation within their areas of jurisdiction.

The review also identified some policy, legal and institutional gaps of relevance to the MWF. These present potential challenges for the implementation of the MWF, as well as opportunities for the MWF to position itself as a response to these gaps. Cross-county cooperation will be essential to the success of the fund. However, the Water Act is not clear on the issue of inter-county linkages, and practical arrangements for trans-county water transfers were not clarified. This has contributed to conflicts among counties in Kenya around water allocations, including tensions among the counties served by the Coast bulk water system. Nevertheless, there are some existing institutions, such as the Council of Governors and Jumuiya ya Pwani, which might be helpful for improving cross-county collaboration among the counties in the region. The finalization of the county joint water authority to take over management of the bulk water supply system from the CWWDA should also help significantly in this regard. As it aims to coordinate catchment conservation funding and activities across multiple counties, the MWF itself can also hopefully contribute to reduced cross-county conflicts. It is also evident that the water fund concept is not explicitly rooted in existing policies and legislations. However, the preceding discussion highlights that the MWF is nevertheless in line with various strategies and legal provision, within which the fund can be anchored and justified. Limited coordination among the various agencies and institutions whose mandates encompass water resource management was also identified as a gap. Different government agencies currently operate in the same space without a framework to guide how they can coordinate their activities. These institutions have their own strategies and budgets and tend to focus attention on meeting specific institutional mandates. Existing regulatory instruments also do not provide frameworks to guide how national government agencies and county governments can coordinate their programs and activities, and engage with community-based conservation groups, such as WRUAs. While this presents a challenge for the MWF to navigate, it also highlights an opportunity for the fund to draw together relevant government agencies and improve their collaboration with each other, and to provide a framework within which various actors can coordinate catchment management interventions.

In sum, the review suggests the MWF is in line with various policies and laws, even though Kenya does not have any dedicated legal provisions for water funds. This includes provision for water catchment conservation and PPPs in a number of existing policies and laws on water and land resources. The water fund can capitalize on these existing frameworks to engage and partner with governments, the private sector and communities in watershed conservation and management. In so doing, it could provide an innovative financing mechanism and a coordinating framework to assist with meeting important strategic goals for the country and helping various government institutions fulfil their constitutional mandates.

10. Stakeholders in a "Mombasa Water Fund"

Our review of the policy, legislative and institutional environment, supplemented by information gathered from existing literature on the Mwache Dam catchment and Mzima Springs recharge area, enabled us to identify various stakeholders of relevance to the MWF. This was followed by engagements with a number of the identified key stakeholders through virtual and in-person meetings in Mombasa and Nairobi. This gave us a clearer understanding of the interests and relevance of various stakeholders in relation to the MWF, allowing us to revise and refine our understanding of the institutional landscape and the roles different stakeholders might play in supporting the MWF. It also provided us with valuable insight into potential barriers and stakeholder concerns that warrant consideration in the design of the fund. Additionally, our engagements also provided an opportunity for the stakeholders themselves to gain a better understanding of the proposed fund.

Following our desktop review and stakeholder engagement process, we classified stakeholders in terms of their estimated level of interest in the MWF and their level of influence over its success. This was done to help determine the appropriate form and level of engagement with each stakeholder. The highest priority stakeholders are those placed in the "work with" category, as they were judged to have both a high interest in the MWF and a high level of influence over its successful implementation. The list of stakeholders considered contains a variety of actors, including key government regulatory and management bodies from national to local level, financing and donor organisations who might have an interest in supporting the MWF as well as private companies and business associations whose operations could be heavily impacted by water availability. The full list of stakeholders analyzed and our assessment of their level of interest and influence can be found in the main text. For the purposes of this summary, we focus on description of some of the most important stakeholders to the fund and the role they might play in contributing to its implementation.

Various national-level government agencies tasked with overseeing water provisioning and resource management would have a role to play in the fund. At the highest level, the Ministry of Water, Sanitation and Irrigation (MoWSI) can help to ensure an enabling policy and legislative framework for the fund. They could also play a role in providing and attracting funding, especially as they have a high vested interest in sediment management interventions to extend the lifespan of Mwache Dam, given that they are the overall implementing agency for the project. The Water Resources Authority (WRA) will be another key national stakeholder, as they undertake catchment management in collaboration with other agencies and have a dedicated water usage levy which is meant to be put towards catchment management. A case could be made to use this levy to contribute to the MWF, though the organization's budget limitations and failure of WSPs to pay this levy could limit its potential contribution. Even if it does not make a large financial contribution, the WRA could provide useful technical expertise around catchment management. The WRA is also mandated to monitor sediment and other water quality parameters. Collection and sharing of these data by the WRA will be essential for monitoring and evaluation of the impact of the water fund interventions on sediment loads and water quality. The Water Services Regulatory Board (WASREB) was identified as another key stakeholder. Although WASREB has limited direct involvement in catchment management, their support could be essential to the fund from a regulatory perspective. This is because they will need to approve any changes to water use tariffs in support of catchment conservation activities, which could be an important source of funding for the MWF.

At the level of regional governance, the Coast Development Authority (CDA) is a key stakeholder for the fund. As a major funder of the Mwache Dam project, the CDA has a large interest in addressing the threat of sedimentation to the lifespan of the dam and has already done extensive work on catchment rehabilitation involving similar interventions to a number of the activities proposed for the MWF. It can thus provide valuable technical and advisory services to the fund, which provides an opportunity to upscale the catchment conservation activities it has conducted to date. The Coast Waterworks Development Agency (CWWDA) has limited scope to contribute directly to the water fund, since its core mandate is the development of water and sewerage infrastructure. However, its operations could be significantly affected by the health of the Mwache Dam catchment, since it will be responsible for development of the water treatment works and will potentially have to operate this plant until the new joint county authority is constituted. It thus has a high vested interest in supporting and advocating for the MWF.

At the local government level, the County Government of Mombasa and the Mombasa Water Supply and Sanitation Company (MOWASSCO) have the greatest interest in sustaining water supply from Mwache Dam, given that Mombasa is set to be the major recipient of water from the dam, which will become the major future source of water in the city. However, as the entirety of the dam catchment lies outside its area of jurisdiction, the Mombasa County Government cannot directly conduct catchment conservation activities itself. Its role is thus limited to providing support to the MWF to conduct catchment management activities in the neighbouring counties. While the ability of the county government and MOWASSCO in particular to contribute to the fund financially may be limited, they could play an important role in advocating for donor funding for the MWF, especially as the city has already received significant funding from development partners and donors to support improvement of its water supply. To help contribute to the MWF financially, the county could apply to WASREB for a tariff revision, on the grounds that the money will be used to support upstream conservation activities. However, the scope to do this might be limited given that tariffs in Mombasa are already some of the highest in the country.

The support of the upstream county governments, particularly Kwale, will also be key to the success of the fund. Kwale was identified as the most important partner as the majority of proposed interventions in the Mwache Dam catchment will take place here. Nevertheless, it will be important to gain support for the fund from all the counties in the catchment to avoid inter-county resentment and competition. The county governments have an important role to play in supporting and facilitating catchment rehabilitation activities within their areas of jurisdiction. Indeed, conservation of water catchments is now a county government responsibility under the Water Act 2016. Some of the proposed MWF interventions also have the potential to bring livelihood benefits to communities in the upstream counties, such as through increased agricultural production. This could be used as a selling point of the MWF to these county governments.

In addition to these government stakeholders, the involvement of the private sector will be important for improving the financial viability of the MWF. In this regard, large individual companies which could play an important role in supporting the fund were identified, as well as business associations which could provide a single point of entry for raising awareness of the fund among member companies. Coastal Bottlers/Coca-Cola and Bamburi Cement were identified as possible companies in the former category as they are major water users in the Mombasa area. Although largely reliant on their own borehole water currently, such companies should be persuaded to support the fund from a business risk perspective, as it could help to diversity the sources of water available to these companies in the future. In addition, the Kenya Manufacturers' Association and Kenya National Chamber of Commerce and Industry were identified as stakeholders that could be used to raise awareness and support for the MWF among other companies. The former association in particular appears to have an increased interest in sustainability and green growth, as evidenced by its creation of a dedicated Centre for Green Growth and Climate Change. The Kenya Coast Tourism Association (KCTA) and its membership also potentially have a high interest in supporting the MWF, given the costs and challenges tourist establishments face as a result of water scarcity in the region.

Finally, the joint water authority which is meant to the take over operation of the Coast bulk water supply network from the CWWDA will be key stakeholder once it comes to fruition. As a single body which unifies all upstream and downstream counties, it could play a key role in coordinating the involvement of the different counties in water fund, improving collaboration and reducing inter-county conflicts. A reduction in the storage capacity of Mwache Dam due to sedimentation would also have a direct impact on the revenues the bulk water authority could generate from water sales to Mombasa and Kilifi counties. The joint authority could also end up being responsible for the high costs of sediment clearing from the proposed check dams. These costs will be directly related to the health of the catchment and the amount of sediment being exported from it. It would thus be in the authority's financial interest to support the fund as much as it can. Integration of catchment conservation costs into the tariff it charges counties for bulk water supplied form Mwache Dam could be one way of doing so. While we have also discussed the possibility of integrating catchment conservation into tariffs charged by MOWASSCO, anchoring the tariff at the level of the bulk WSP could be fairer and less contentious. This is because it would result in counties contributing to the fund in direct proportion to the amount of water they use, providing an objective way of determining how much individual counties should contribute to the MWF.

PART V. IMPLEMENTING THE MWF

11. Financing and implementing the MWF

The MWF will have the ability to receive, generate, manage and spend funds through endowment and revolving facilities, as well as to guide aligned public investment for financing the above interventions. For example, the revolving fund could provide a vehicle to prepare the groundwork while raising capital for the endowment fund, e.g., by funding the immediate initiation of priority interventions while the endowment is being capitalized. Funding would be provided by domestic and international donors and water charges, and ultimately also from interest from the endowment fund. Public and private investment may also take the form of non-monetary actions that are aligned with the MWF, such as staff assignments to undertake MWF activities in the designated water source areas, or legal assistance.

It is estimated that the average total annual budget that the MWF will need to carry out its mission effectively and efficiently will be approximately US$8.8 million. Interventions in the Mwache catchment would require an initial expenditure of US$6.4 million followed by annual payments of US$2.2 million, while those in Mzima Springs recharge area would require a smaller upfront investment of US$2.1 million but much higher ongoing payments of US$6.3 million per year. The origination and establishment costs which include costs for the MWFs financial, legal and institutional structuring are estimated to be in the region of US$300,000. The annual costs can be expected to be in the region of US$275,000 per year and would include salaries, vehicles, office rent and equipment, marketing and communications, training, audit and miscellaneous costs.

Given the size of the overall investment required, it is likely that the MWF would need to aim to raise an initial sum, say $20 million, which could generate a net average annual income of about US$1 million (based on the 5% spending policy), and through demonstrating the success of initial endeavors, obtain further commitments over time. Broadly adopted by most US NGOs and charitable foundations as a sensible baseline for spending, a 5% spending policy means an organisation must achieve a return of 5% plus the rate of inflation to support the organisation in perpetuity. Future funds could also be pledged conditional on measure of success.

The protection of investments in water security is the main purpose of the MWF. As such, the primary beneficiary is the State, more specifically its organs responsible for raw water supply infrastructure. Therefore, there is strong motivation for a contribution from the sale of raw water, some or all of which could be passed on to the county government water service providers. A modest KSh2/kl catchment conservation levy could generate annual revenues of US$1.3 million for expenditure on MWF activities in Mwache Dam catchment and US$0.7 million per year for Mzima Springs recharge area. This would also greatly encourage co-funding by other national and international stakeholders. For example, The World Bank as funders of the Mwache Dam, will be interested in the protection of their investment. Indeed, initial expenditure for effective intervention in the Mwache Dam catchment (US$6.4 million) represents just ~3% of the US$200 million dam development cost.

Furthermore, it is also envisaged that some funders e.g., motivated by carbon, biodiversity or other gains, might need to see ringfenced funding "pots" for specific projects, such as the Chyulu Hills water PES scheme. Implementation of the Chyulu Hills PES could be relatively straightforward given the already operational Chyulu REDD+ Project through which it will operate. However, revenues from the recommended KSh2/kl water charge (US$0.7 million per year) for water supplied from the Springs would cover only a small portion of the annual payment. Significant amounts would need to be fundraised to increase the endowment or be received through grants and donations to cover the costs of the PES scheme fully. This is not an impossible feat given the rich biodiversity of the landscape and the significant existence and bequest values attached to it.

Implementation of the restoration and conservation activities can be undertaken using different types of incentive and assistance-based approaches. The Business Case proposes a range of complementary and mutually-supportive types of assistance to be funded in order to bring about the land and resource management interventions required in different parts of the two priority water source areas. These include, but are not necessarily limited to, the following:

- ***Direct assistance to farmers*** in Mwache catchment to implement and maintain soil conservation measures, by the Kwale County government and with the assistance of an NGO;
- ***Establishing and financing environmental restoration teams*** which comprise trained core personnel and locally employed labor to undertake vegetation restoration and rehabilitation measures, particularly in the Mwache Dam catchment;
- ***Setting up payments for ecosystem services (or PES-like schemes)*** in the Mzima Springs recharge area (Chyulu Hills water PES scheme) and Mwache Dam catchment (within the western pastoral/conservancy landscape) to incentivize the restoration and maintenance of woody resources and rangeland ecosystem health; and
- ***Encouraging and assisting with the establishment of new conservancies*** and other community or landowner associations that might be incentivized by and able to benefit from PES-type funding or other opportunities in both water source areas.

The way in which these projects are designed and implemented is key to their success. The farmer assistance model seeks to emulate the success of large-scale soil conservation programs combining government extension staff, donor agencies and NGOs in other parts of Kenya. For example, successes in Machakos County under the National Soil and Water Conservation Programme show the potential for large-scale adoption of terracing and other soil conservation measures given adequate training, extension support and tools for local farmers. Following multiple soil conservation programs in Machakos, over half of all arable land and 83% of land in hilly areas had been adequately conserved by 1985. About half of this growth was attributed to unassisted farmers who spontaneously adopted conservation measures following their general success in the region. In the Mwache Dam catchment area, the Kwale County Government's Agriculture department would be best placed to take the leading role in helping farmers to set up their terraces and associated measures, through extension services and direct support in terms of assisting farmers with earth works and other labor-intensive work. Grants could also be provided to NGOs with relevant expertise and interests, to either directly assist farmers themselves or to work in partnership with the county government. Numerous NGOs in Kenya currently provide assistance and training to farmers around similar interventions to those proposed under the MWF. Additionally, the CDA has worked extensively with farmers to reduce soil erosion as part of KWSCRP-2 project and could thus provide valuable advisory support to the MWF from their experiences to date.

It is recommended that the direct rehabilitation of badly degraded areas is undertaken by trained restoration teams. It would not be feasible to expect widespread adoption of these practices among communities. However, the program should be designed to use local laborers, so that the activities create employment. This program should maintain a long-term business relationship with the local laborers to ensure that the planted vegetation survives and thrives. Training support could be provided by staff from government agencies with relevant expertise. These potentially include the environmental departments of county governments and staff from the CDA and WRA with recent experience conducting rehabilitation activities in the Mwache Dam catchment. Additional technical support could be provided by NGOs such as Vetiver Network International or companies with expertise in land restoration.

In the Mzima Springs recharge area and Mwache Dam catchment area, PES (or PES-like schemes) could be used to incentivize the restoration and maintenance of woody resources and rangeland ecosystem health (as part of the sustainable natural resource management intervention which involves incentives to reduce overgrazing and control overharvesting of fuelwood in degraded areas). In such a PES scheme, the buyer would by the MWF, acting on behalf of the water beneficiaries. PES schemes are one of the few options available to leverage an improvement in catchment management. The use of PES may in fact provide a stimulus (the financing required) for the development of conservation areas through the establishment of new conservancies and other community or landowner associations. In the northern part of the Mwache Dam catchment a large block of natural vegetation that lies between the Tsavo East National Park and the Shirango conservancy has been identified as a potential site for the establishment of a community wildlife conservation area.

Within forest, woodland or bushland areas, the primary aim of a PES scheme or wildlife conservancy would be to reduce the rate of woody vegetation loss due to unsustainable harvesting or clearing for agriculture and encourage vegetation recovery. It would also discourage overgrazing and encourage the maintenance of grass cover. Within the Mzima Springs recharge area, woody vegetation cover and biomass can be easily and objectively measured using satellite data. Indeed, there is already a robust forest and vegetation monitoring program in place as required under the VCS VM 009 methodology under which the REDD+ project is accredited. Within the Mwache Catchment, monitoring and measuring ecosystem condition will need to include on-the-ground field surveys which are already undertaken on the Wildlife Works Kasigau Corridor REDD+ Project ranches. The PES-like scheme could also focus on riparian areas, a primary aim being to create and maintain riparian setback areas that are free of cultivation and resource use, where natural vegetation can re-establish itself, as well as to protect these areas from activities that lead to erosion, including unmanaged watering of livestock and sand mining. The outcome would be easily and objectively measured using satellite data.

Given that PES schemes have been implemented in Kenya with mixed success, it is important that institutional pre-requisites and key design elements are properly addressed. The important set of institutional pre-requisites is that the communities involved are well defined with clear, trusted leadership, and have a well-defined, designated conservation area under their control. The important set of design elements is that the measurement of conservation outcomes is determined and executed by an independent party and is well understood by the communities, and that the payments are conditional on conservation outcomes, and are high enough to incentivise the practices that lead to these outcomes. In the absence of a strong community structure or secure land tenure in this landscape, it is recommended that communities (not too large) are invited through a roadshow to organise themselves and bid to opt into the PES scheme. This will avoid having to work directly with individual farmers in the group. Given that local leaders have been benefitting from active deforestation, the scheme design will need to ensure that they will gain more from ensuring protection. The communities that share common grazing areas may also be encouraged to cooperate with one another. Participating communities could be given exclusive rights to harvest sand, for example, on condition that it came from one designated site that is managed according to strict environmental protocols.

For the Chyulu Hills landscape, the MWF can build on existing institutional, governance, financial management and operational capacities through the existing REDD+ project. However, it is recommended that a strong element of conditionality is introduced.

A Water Fund is a funding and governing mechanism which provides sustainable funding for watershed conservation. It has demonstrated the potential to advance economic incentive mechanisms such as PES by serving as an instrument for financial administration and an intermediary between buyers and sellers of ecosystem. Water funds mobilize and invest funds from urban water users and other donors, and re-grant to a range of stakeholders. It also connects urban users of watershed ecosystem services to upstream land managers through a governing entity. There are various water fund governance models that exist, including (i) multi-stakeholder public-private partnership model, (ii) government-operated model, (iii) civil society-operated model, (iv) watershed committee model, and (v) private sector-operated model.

The multi-stakeholder public-private partnership (PPP) model provides the most scalable avenue for coordinating and providing long-term resources for catchment protection and conservation. A diverse PPP model can harmonize private and public sector interests and combine entrepreneurial and government investments. Furthermore, policy, legal and institutional frameworks have been developed and established to regulate the process of engagement with private parties and implementation of project agreements. Through seeking to draw funding and technical support from a range of actors, including private companies and government agencies, as well as donors and NGOs, the multi-stakeholder PPP is effectively a hybrid approach which combines the strengths of a number of the other governance models (e.g. combining government, private and CSO actors). It has a proven ability to mobilize not only financial resources, but also to draw on the technical capacity of diverse collaborative partners, thus overcoming some of the weaknesses that are associated with the other models. For example, government financing of sustainability initiatives is often limited to small-scale/narrow projects, particularly in the context of Kenya. Hence, government funding alone is unlikely to be sufficient to cover the scale of interventions proposed under the MWF, limiting the potential of a purely government-operated model. Similarly, private sector financing of sustainability projects may result in a relatively small budget which funds activities in the name of corporate social responsibility initiatives, which again are insufficient to match the scale of interventions proposed. Overall, PPP thus has the greatest potential to close the financing gap in environmental conservation and management, while ensuring the inclusion of governmental and non-governmental actors who can provide the required technical support to guide the fund's investment and intervention strategies.

Specific policy recommendations are as follows:

- Capitalize on existing policy, legal and institutional frameworks on sustainable natural resources management.
- Tap into opportunities for multi-sectoral linkages and public-private partnerships.
- Capitalize on the funding gap for watershed management.
- Explore innovative revenue streams to increase conservation finance.
- Focus on natural resources management policies that promote community participation in water and forest governance.
- Promote PPP models that optimize participation from civil society organizations.

12. Proposed structure of the MWF

Based on our prior analysis of potential water fund stakeholders, funding and governance models, we propose that the MWF takes the form of a multistakeholder public-private partnership. It will ideally receive payments and in-kind support from a range of contributors, including government, the private sector and international donors. Drawing on the success of the UTNWF, it is recommended that the actual fund should be established as a charitable trust under Kenyan law, so that it will be exempt from income tax. While a number of the contributors to the Fund will be beneficiaries in their capacity as water consumers, the fund itself is considered the "buyer", as it the source of the payments that will be made to various service providers to achieve catchment conservation outcomes and ultimately water security for the City of Mombasa. Partnerships with local NGOs, research organizations and various government bodies can also play an important role in providing advisory services and assisting with the implementation and monitoring of proposed water fund activities. A broad depiction of the proposed structure of the MWF is shown below (Figure V).

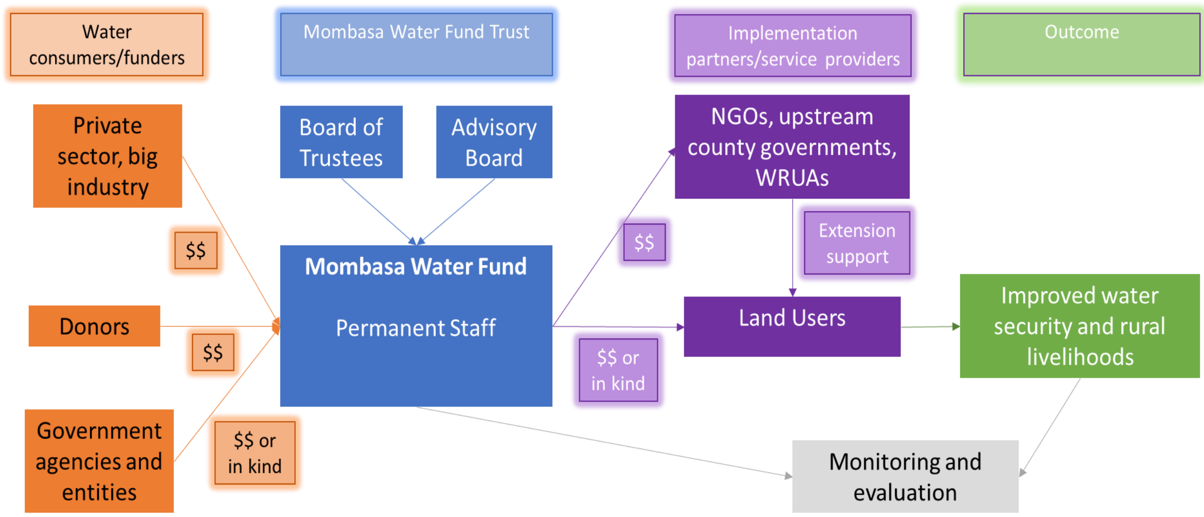


Figure V. Broad schematic of the proposed organizational structure of the Mombasa Water Fund. This is just one potential option of what the structure of the Fund could look like.

The Mombasa Water Fund Trust will be the body responsible for activities such as fundraising, financial and investment management and deciding how best to carry out the proposed activities. As is typical for a charitable trust, it will be headed by a Board of Trustees (BoT) who will be held accountable for achieving the goals of the water fund. The BoT will replace the current steering committee once incorporation of the fund as a charitable trust is finalized. It will ideally be a relatively small body (10 members or less) which will include representatives from organizations with the greatest financial stake in the water fund as well as important government regulators. This will potentially include representatives from MOWASSCO and/or the County Government of Mombasa, the bulk water authority (CWWDA or the new joint authority), WASREB and a representative from the MoWSI and/or the WRA. One would also expect TNC to be a member of the BoT, along with representatives of any major donor funding partners which contribute to the fund. It could also include one or two representatives of any private sector companies which make a significant financial contribution to the fund.

We also propose that the fund have an advisory board, potentially supported by one or more technical committees. The advisory board will provide over-arching managerial and technical support to help the fund achieve its aims. To minimize staffing costs, these roles will ideally be filled on a voluntary basis by stakeholders whose interests or mandates are aligned with the fund's goals. For example, county governments could provide advisory support to the fund by seconding staff to the advisory board, which in turn could help them fulfil their mandated duties around environmental conservation and catchment management. Staff from the WRA and CDA would be well placed to provide similar assistance, given their experience of implementing catchment management interventions in the Mwache Dam catchment. Other public agencies such as the Kenya Forest Service (KFS) and Kenya Agricultural and Livestock Research Organization (KALRO) can also provide useful technical and advisory support, as their expertise and interests encompass many of the interventions proposed under the water fund. To avoid the advisory board becoming too large and cumbersome, it could be wise to rather include a number of these technical experts on one or more technical committees (e.g. a technical committee for catchment conservation interventions). Members of the advisory board tasked with financing, investments and fundraising could be sourced from private companies which have made a significant contribution to fund.

A relatively small number of permanent staff will be responsible for the day-to-day operation of the fund. We propose that this will include a CEO, a finance and administration officer, one or two officers in charge of catchment management programs and a monitoring and evaluation officer. These staff would need to be provided with an office and vehicles to allow them to perform their duties. The permanent water fund staff will liaise with implementation partners to carry out the fund's proposed activities. This will include making decisions about how to allocate available funding for the proposed activities and to whom, in line with the policy direction and rules set by the BoT and guidance given by the advisory board and technical committee(s).

As noted elsewhere, it is envisaged funding will be provided by the main beneficiaries of the MWF (*i.e.* water consumers) as well as donors and private sector companies. The costs of sedimentation of the Mwache Dam will ultimately be borne by water users in Mombasa, in terms of worsening water shortages and/or potential tariff increases as water from Mwache Dam becomes more expensive due to sediment clearing and water treatment costs. These costs will also impact the operations of the bulk WSP in terms of the quantity of the quantity of water they can sell and the treatment costs they incur. This places a strong financial incentive on MOWASSCO and/or the county government of Mombasa to support the fund, as well as the CWWDA (currently) or the new joint water authority in the future. Additionally, it was suggested that major water users from the private sector could contribute to the fund, as way of minimising business risk through ensuring sustained future water supply for their businesses. As was the case with the UTNWF, TNC is likely to play a key role in providing seed capital for the MWF and lobbying for support from the various other potential funders identified here. Since TNC and AFD together identified the opportunity for the development of the MWF, AFD could also provide valuable assistance in this role. A number of donors and financing institutions which may have an interest in supporting the MWF have been identified in the report, though the list is by no means exhaustive.

To implement the proposed activities or provide funding to implementation partners. Given the degree of overlap between the proposed activities of the MWF and mandate of counties to improve livelihoods, conduct catchment and natural resource management and support agricultural development, there could be potential for co-financing agreements between the MWF and the upstream county governments in implementing proposed activities as part of the fund. In this way, the water fund activities can be integrated with into county government plans and help them fulfil their constitutional mandates. Alternatively, or in addition to the upstream county governments, NGOs and CBOs with expertise in conducting soil erosion control and land restoration activities in the region could be important implementation partners and potential recipients of grants from the MWF. If sufficiently capacitated, WRUAs could represent useful community-level implementing agents for the proposed activities.

TABLE OF CONTENTS

ABBREVIATIONS AND ACRONYMS

AFD	*Agence Française de Développement*
AfDB	African Development Bank
ANR	Assisted Natural Regeneration
AWWDA	Athi Water Works Development Agency
BAU	Business As Usual
BWRC	Basin Water Resources Committee
CA	Conservation Agriculture
CAAC	Catchment Area Advisory Committee
CBA	Cost-benefit Analysis
CBO	Community-based Organisation
CDA	Coast Development Authority
CECM	County Executive Committee Member
CHCT	Chyulu Hills Conservation Trust
CIDP	County Integrated Development Plan
CSO	Civil Society Organisation
CWWDA	Coast Water Works Development Agency
ECMWF	European Centre for Medium-Range Weather Forecasts
EMCA	Environment Management and Coordination Act
EPA	Environmental Protection Agency
ESA-CCI	European Space Agency - Copernicus Climate Change Initiative
ESC	Environmental Safeguards Consultants
ESIA	Environmental and Social Impact Assessment
ESMP	Environmental and Social Management Plan
FAO	Food and Agriculture Organisation
FMNR	Farmer-Managed Natural Regeneration
FRL	Full Reservoir Level
GDP	Gross Domestic Product
GEF	Global Environment Facility
GFW	Global Forest Watch
GloREDa	Global Rainfall Erosivity Database
GSOD	Global Surface Summary of the Day
GSCC	Global Social Cost Of Carbon
HES	Hydrologic Ecosystem Services
HRU	Hydrological Response Unit
HWC	Human Wildlife Conflict
KALRO	Kenya Agricultural and Livestock Research Organisation
KEFRI	Kenya Forestry Research Institute
KFS	Kenya Forest Service
KNBS	Kenya National Bureau of Statistics
KWCA	Kenya Wildlife Conservancies Association
KWS	Kenya Wildlife Service
KWSCRP-2	Kenya Water Security and Climate Resilience Project – Phase 2
KWTA	Kenya Water Towers Agency
IAM	Integrated Assessment Model
ICLM	Integrated crop-livestock management
InVEST	Integrated Valuation of Ecosystem Services and Tradeoffs
ISRIC	International Soil Reference and Information Centre
IWRM	Integrated Water Resources Management
LDN	land Degradation Neutrality
LSDF	Land Degradation Surveillance Framework
MDDL	Minimum Draw Down Level

MOWASSCO	Mombasa Water Supply & Sanitation Company
MoWSI	Ministry of Water, Sanitation and Irrigation
MTP	Medium-term Plan
MWF	Mombasa Water Fund
NbS	Nature-based Solutions
NDVI	Normalised Difference Vegetation Index
NEAP	National Environment Action Plan
NEMA	National Environment Management Authority
NEP	National Environment Policy
NESCRA	National Environmental Sanitation Coordinating and Regulatory Authority
NIA	National Irrigation Authority
NGO	Non-governmental Organisation
NLC	National Land Commission
NLP	National Land Policy
NLUP	National Land Use Policy
NPV	Net Present Value
NRW	Non-revenue Water
NWMP	National Water Master Plan
NWSH	National Water Harvesting and Storage Authority
PES	Payment for Ecosystem Services
PPP	Public-Private Partnership
PUD	Photo-user Day
REDD+	Reduced Emissions through Degradation and Deforestation
RGS	River Gauging Station
ROI	Return on Investment
ROOT	Restoration Opportunities Optimization Tool
RTI	Research Triangle Institute
RUSLE	Revised Universal Soil Loss Equation
SCAP	Sub-catchment Action Plan
SCMP	Sub-catchment Management Plan
SDR	Sediment Delivery Ratio
SDU	Spatial Decision Unit
SEI	Stockholm Environment Institute
SLM	Sustainable Land Management
SWAT	Soil and Water Assessment Tool
SWRO	Seawater Reverse Osmosis
SWSA	Strategic Water Source Area
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
TNC	The Nature Conservancy
TTRA	Taita Taveta Ranches Association
TTWCA	Taita Taveta Wildlife Conservation Association
UDDT	Urine Diverting Dry Toilet
UN	United Nations
UTNWF	Upper Tana Nairobi Water Fund
WASREB	Water Services Regulatory Board
WB	World Bank
WEAP	Water Evaluation and Planning tool
WMO	World Meteorological Organization
WRA	Water Resources Authority
WRUA	Water Resource User Association
WSP	Water Service Provider
WSTF	Water Sector Trust Fund

GLOSSARY

Adaptive Management
Adaptive management is a systematic approach to learning and managing protected areas and natural resources that allows managers to make decisions despite uncertainty. It is an iterative process with six stages: problem assessment, experimental design, implementation, monitoring results of experiment, evaluation of results, and management adjustment.

Business-As-Usual Scenario
The Business-as-Usual (BAU) Scenario assumes management of the Western Area Peninsula Water Supply System continues as it is currently being implemented with no significant new investments in forest protection or restoration and that unmanaged urban and agricultural expansion continues.

Carbon Sequestration
Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide. Natural carbon sequestration processes can be supported through changes in land use and agricultural practices, including forest restoration and the conversion of annual cropping systems and livestock grazing land into agroforestry systems.

Conservation Scenario
The Conservation Scenario assumes significant investments in interventions aimed at halting and reversing the deforestation that has taken place in the WAPNP, as well as to preserve and restore forest areas in the riparian zones of the urbanized areas below the Park. It also assumes substantial investments in a suite of enabling interventions that seek to enhance the impact of the interventions directly aimed at forest conservation and restoration.

Currency
All monetary values are expressed in United States Dollars (USD). All estimates were calculated using the exchange rate of US$1 = 107.5 KSh.

Catchment
A catchment is an area where water is collected by the natural landscape. Precipitation that falls in a catchment runs downhill into creeks, rivers, lakes, oceans, or into built infrastructure, such as reservoirs. In this document, the terms catchment and watershed are used interchangeably.

Cost Benefit Analysis
Cost-benefit analysis is a conceptual framework and tool used to evaluate the viability and desirability of projects or policies based on their costs and benefits over time. It involves the adjustment of future values to their present value equivalent by discounting at a rate which reflects the potential rate of return on alternative investments or the rate of time preference.

Discount Rate
Refers to the interest rate used in discounted cash flow analysis to determine the present value of future cash flows.

Ecological Infrastructure
Ecological infrastructure is the nature-based equivalent of grey or engineered infrastructure. It forms and supports a network of interconnected structural elements such as catchments, rivers, riparian areas and natural corridors supporting habitats and movement of animals and plants.

Ecosystem Services
Ecosystem services are the benefits people obtain from the Earth's many life-support systems. The Millennium Ecosystem Assessment defines four categories of ecosystem services: provisioning, regulating, cultural, and supporting services.

Mombasa Water Supply System
The Mombasa Water Supply System is all of the ecological and built infrastructure, which together supply water to meet the needs of the population of the city of Mombasa as well as the surrounding coastal towns and inland towns as far as Voi.

Nature-Based Solutions
Nature-based solutions are actions taken to protect, sustainably manage, and restore ecosystems to effectively address societal challenges, such disaster risk reduction. Nature-based solutions simultaneously improve ecosystem health and functioning to the benefit of human and non-human nature.

Net Present Value
Net present value (NPV) is a calculation used to estimate the value — or net benefit — over the lifetime of a particular project. NPV allows decision makers to compare various alternatives on a similar time scale by converting all options to current dollar figures. A project is deemed acceptable if the net present value is positive over the expected lifetime of the project.

Payments for Ecosystem Services (PES)
Payments for ecosystem services schemes involve beneficiaries of ecosystem services compensating ecosystem managers (land owners or resource stewards) to change their practices in order to secure those ecosystem services. This may involve desisting from damaging activities, or adopting more expensive practices that are less damaging to the environment.

Recharge Area
The area where rainwater seeping into the ground is able to reach and replenish an underground aquifer because no confining layer is present. In this study it includes the Chyulu Hills Water Tower and the wider drainage area beyond the hills themselves.

Return on Investment
Return on investment (ROI) is a simple ratio of the gain from an investment relative to the amount invested. ROI is calculated by dividing net profit (current value of investment — cost of investment) by the cost of investment.

Riparian Area
Land occurring along watercourses and water bodies. For the purpose of this study it can be defined as the area within 50 m of the river channel.

Water Fund
A Water Fund is a funding and governance mechanism that enables water users to provide financial and technical support collectively in catchment restoration alongside upstream communities.

Water Security
Water security is the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality of water for sustaining livelihoods, human wellbeing, and socio-economic development, for ensuring protection against waterborne pollution and water-related disasters and for the preservation of ecosystems in a climate of peace and political stability.

PART I. BACKGROUND & STUDY CONTEXT

1 INTRODUCTION

PROJECT BACKGROUND AND RATIONALE

Many cities and regions around the world face increasing pressures on their water supplies and other hydrological ecosystem services as a result of growth in urban demand and/or degradation of water source areas. Managing land uses, particularly in the upstream catchments, can ensure year-round water availability and improve water quantity for domestic use and for environmental flows. Recognising this, investments in nature-based source water protection are taking root (Brauman *et al.*, 2019). Water Funds have been established in many developing country contexts in order to facilitate such investments. These typically support nature-based solutions (NbS), either alone or in conjunction with grey infrastructure measures, in order to achieve maximum overall long-term benefits and return on investment (ROI). The first of these water funds in Africa was the Upper Tana Nairobi Water Fund (UTNWF) in Kenya that now benefits a wide range of stakeholders and helps to meet water demands in Nairobi.

The *Agence Française de Développement* (AFD) and The Nature Conservancy (TNC) have identified an opportunity to establish a similar Water Fund for Mombasa, the second-largest city in Kenya. The proposed "Mombasa Water Fund" (MWF; a provisional name)[1] would be designed to improve water security for Mombasa City and a number of other smaller towns in southeastern Kenya that depend on the same water sources. The MWF would aim to reduce land degradation in water source areas to ensure long-term sustainability of the benefits from major water supply infrastructure investments that are currently under construction in order to address major water supply shortages in this region.

Given that the present spring- and groundwater-based water supply infrastructure is insufficient to meet the city's growing demands, the city will also be served by a multipurpose surface water dam (Mwache Dam) that is set to be constructed in the near future through funding from the World Bank[2] (KWSCRP, 2014).

The risks identified in the Mwache Dam catchment are numerous and have the ability to diminish water quality, water use efficiency, conservation outcomes and land productivity. The MWF could address these through the implementation of nature-based solutions, which are defined as "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits". The growing scientific evidence base on nature-based solutions suggests that these are often more cost-effective than traditional responses such as the augmentation and upgrading of water supply infrastructure. This is especially the case when their co-benefits are considered. Nature-based solutions contribute to biodiversity conservation, can help to reduce disaster risk, improve health and livelihoods, and can help countries to meet their international climate mitigation goals (IUCN, 2021). Nevertheless, it is important to select locally appropriate interventions that are likely to yield

1 For ease of reporting, we refer to the water fund as the Mombasa Water Fund (MWF). However, the name of the water fund is yet to be finalised and will be done so through consultations with stakeholders.

2 https://projects.worldbank.org/en/projects-operations/project-detail/P145559

positive outcomes for both the communities in the implementation areas as well as sustained benefits for the downstream water service providers and users.

The potential viability of the MWF was confirmed by a pre-feasibility study (Rural Focus Ltd, 2020). The prefeasibility study provided a review of the policy and legal landscape, water demand and supply, the risks to water supply and potential activities to be funded, as well as stakeholder mapping and analysis, and an economic analysis. Stakeholders relating to water service delivery and catchment management were identified, as well as the water users. The study identified the catchment area for the Mwache Dam and the recharge area for Mzima Springs as particularly important areas for the implementation of conservation interventions. The Mwache Dam catchment area was found to be degraded as a result of poor farming practices and rangeland management, deforestation, sand harvesting and quarrying, resulting in high erosion and sediment risk to the Mwache Dam. The Mzima Springs recharge area is being degraded by grazing pressure, fire and charcoal production. The study estimated that conservation measures in Mwache Dam catchment (e.g. terracing, conservation agriculture, rangeland management, agroforestry, and in-situ soil and water conservation technologies) would yield positive net benefits through reducing sediment loads and extending the life span of the reservoir, as well as through improved soil fertility and crop yields.

STUDY OBJECTIVES

This study has been commissioned to build on the work of the pre-feasibility study and related activities undertaken by TNC, the World Bank's Kenya Water Security and Climate Resilience Project (KWSCRP-2), and the AECOM/GNI Plus's Chyulu Hills Water PES scheme project, to advance the design and business case. The purpose of the consultancy is to develop a design study covering the following elements:

- Assess the technical, financial, economic and socio-economic benefits and challenges of the MWF; and
- Identify the potential governance and financing models to establish the MWF and formulate recommendations on the proposed model that can enable achieving financial sustainability, so as to provide a clear plan to the AFD, TNC and local actors as to how to move forward with the creation of the MWF.

SCOPE OF THE STUDY

The MWF is primarily focused on the Mwache Dam catchment area and the Mzima Springs recharge area. The technical aspect of this study focused on the Mwache Dam catchment area, since nature-based solutions for the Mzima Springs recharge area were already being investigated and designed under a separate initiative being undertaken by GNIplus in collaboration with AECOM. Their study has furnished a description of the recharge area, its hydrology, and the expected effect of implementing natural resource management measures focused on overgrazing and woody resource use on the recharge and yield of the Mzima Springs. These estimates were used in combination with the proposed Mwache Dam catchment interventions to evaluate their combined impacts on sediment yield, water quality and water yield.

The prefeasibility study used the hydrological data from three earlier studies (Design Report on Mwache Multipurpose Dam Development Project 2014, Mwache Dam Design Review

Report 2017, and Mwache Physiographic Report 2017[3]) all with slightly different hydrological approaches and varying estimates of sediment yields and accumulation rates. The analysis did not include estimates of co-benefits. This study builds on the work already undertaken by:

- Quantifying all hydrological benefits and other co-benefits (storage infrastructure cost savings, water treatment cost savings, water supply cost savings for those directly dependent on instream water, improvements to rangeland and agricultural productivity, impacts on crop pollination, carbon storage, and biodiversity conservation) using the latest hydrological modelling tools and spatial models for the assessment of non-hydrological ecosystem services;
- Determining which combination of conservation interventions and in what location will yield the greatest returns on investment using an iterative scenario analysis approach where more than one conservation scenario is assessed (this is an important departure from previous Water Fund studies which have been limited by the requirement to estimate the conservation scenario in advance of hydrological modelling);
- Conducting a more thorough evaluation and cost analysis of potential conservation (and other) interventions through focused stakeholder engagement (semi-structured interviews and focus group discussions) in order to determine acceptability of the interventions across various stakeholder groups; and
- Developing a financial sustainability strategy for the MWF through financial modelling analysis.

The study involved five inter-related work streams:

- **Biophysical analysis**, to determine the most efficient combination of solutions (nature-based, possibly in combination with other types) to meet water quantity and quality objectives and inform effects on ecosystem services;
- **Economic analysis**, involving the design, costing and valuation of alternative scenarios and their outcomes, and development of the business case;
- **Socio-economic analysis**, to understand the socio-economic context, stakeholder positions, capacity, motivation and potential support relating to the proposed activities, assess levels of risks and measures to mitigate risk;
- **Institutional analysis**, to understand the relevant institutions and identify governance models that could be established to set up the Water Fund, raise funds and implement the proposed management measures; and
- **Financial analysis**, to define a financially sustainable strategy for the MWF, by modelling costs and revenues of the MWF as a whole, and identifying means to cover costs as well as to cover any financing gaps, under a range of assumptions.

[3] Referenced as CES 2014; Nippon Koei et al. 2017; RTI/ICRAF 2017 in the MWF prefeasibility study.

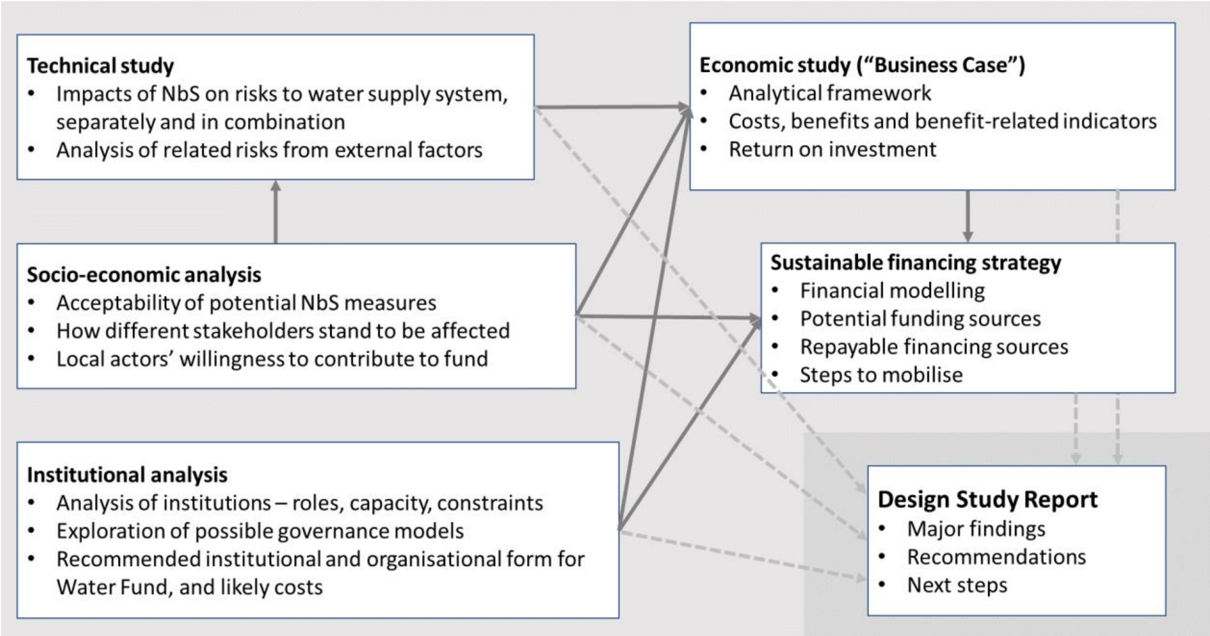


Figure 1-1. Summary of the study components

STRUCTURE OF THE REPORT

The rest of the report is structured as follows:

Part I provides the background and study context. **Chapter 2** provides a description of how water funds work, giving examples from the region. **Chapter 3** provides a description of Mombasa's water supply situation, how this is expected to change over time, and the existing plans to improve water security. In **Chapter 4**, we provide an overview of the ongoing infrastructure developments and associated activities.

Part II provides the rationale and analysis for the proposed type, location and extent of nature-based interventions in the priority water source areas. **Chapter 5** provides a detailed overview of the biophysical and socio-economic characteristics of the Mwache Dam catchment area, and describes its degradation. A literature review of potential conservation interventions is presented, and then suitable interventions are selected based on biophysical and social considerations. Their potential location and extent is mapped, and finally, we use an optimization model to determine priority areas for intervention. In **Chapter 6**, we summarise the existing and proposed interventions for the Mzima Springs Recharge Area, based on the concurrent study by AECOM.

Part III develops the business case for the Mombasa Water Fund. **Chapter 7** starts with the hydrological modelling of the impacts of the proposed interventions. This describes the modelling approach for the Mwache Dam catchment, its baseline hydrology and the impacts of the proposed interventions on surface water flows, sediment yields, water quality and dam yield. This is then combined with the effects of the proposed interventions in the Mzima Springs recharge area in order to simulate the combined impact of interventions in both areas on Mombasa's water supply. **Chapter 8** estimates the expected co-benefits of the conservation activities, and uses cost-benefit analysis to estimate the overall the return on investment.

Part IV provides an overview of the policy, legal and institutional context for the proposed MWF, the key stakeholders and potential governance arrangements, and considers the potential financing mechanisms for the fund. **Chapter 9** describes the key policies, legislation, strategies and plans and institutions relating to water services provision and catchment management. **Chapter 10** provides an overview of the key stakeholders and the potential role of key stakeholders in the MWF.

Part V outlines the implementation and financing of the MWF. **Chapter 11** estimates how much budget the Water Fund will need each year to achieve its outcomes and provides a brief review of financing mechanisms for Water Funds. It also provides a review of governance structures of water funds and considers possible governances structures for the MWF. Finally, **Chapter 12** proposes an organizational structure for the MWF.

2 WATER FUNDS

HOW WATER FUNDS WORK

Water funds provide a means by which finance and assistance from downstream beneficiaries (e.g. water service providers) and donors (motivated by developmental and/or biodiversity conservation benefits) can be channeled to the actors that bring about and/or tolerate management changes and conservation actions in important water catchment areas (Figure 2-1). Such actors could be, to name some examples, the land owners or users in catchment areas who change their practices, government agencies who strengthen and expand protected areas, or private companies or individuals who are hired to undertake labour-intensive reforestation.

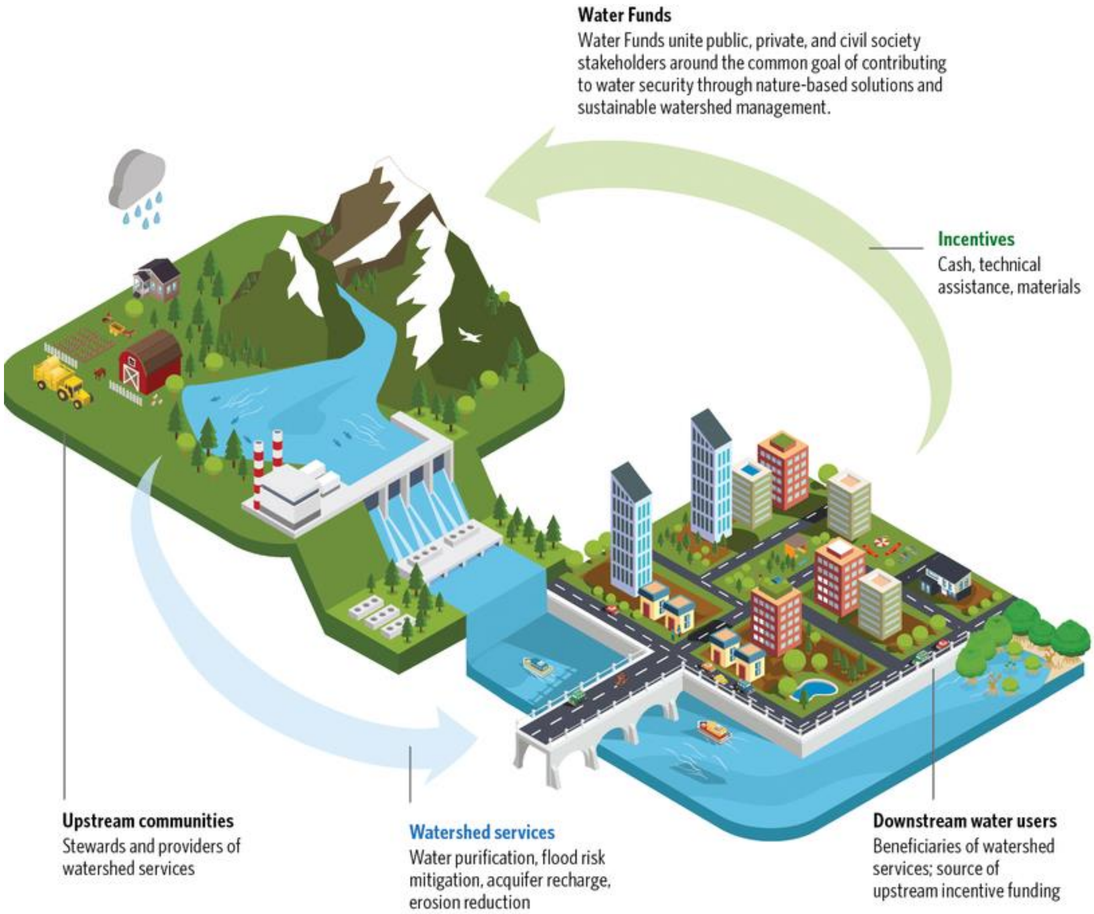


Figure 2-1. The Water Fund model. Source: The Nature Conservancy

Water Funds can be defined as "organizations that design and enhance financial and governance mechanisms which unite public, private and civil society stakeholders around a common goal to contribute to water security through nature-based solutions and sustainable watershed management"[4]. This definition is based on six defining features that are used to guide the development and implementation of water funds (Figure 2-2).

4 TNC. 2018. Water Funds: Field Guide. Arlington, VA: The Nature Conservancy.

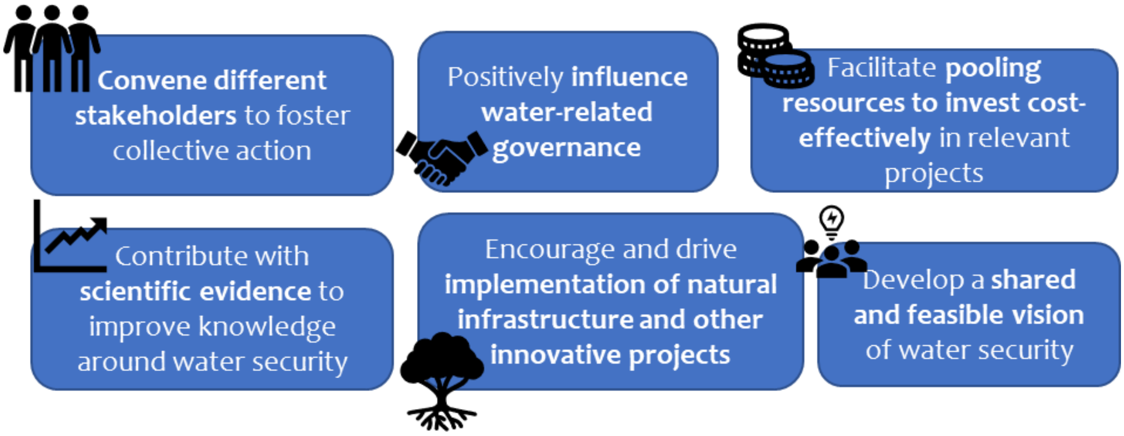
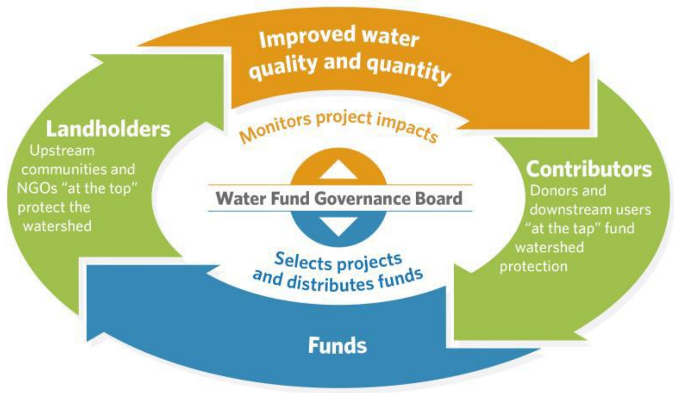


Figure 2-2. The defining features of a water fund. Adapted from https://waterfundstoolbox.org/.

The Water Fund concept represents a potential solution to challenges of environmental degradation in water source areas. Water funds provide a means by which finance and assistance from downstream beneficiaries (e.g. water service providers and consumers) and donors (motivated by developmental and/or biodiversity conservation benefits) can be channeled to the actors that bring about and/or tolerate management changes and conservation actions in important water catchment areas. Water funds thus provide a financing and governance mechanism for linking downstream water consumers with upstream land users, typically taking the form of a public-private partnership.



Water Funds provide financial support to activities which promote restoration and sustainable land management practices that improve downstream water quality and/or quantity. A key premise of the Water Fund approach is that it is cheaper to prevent water problems at source than to address them later. Funding is also used to support economic opportunities that enhance livelihoods for local communities, including agricultural interventions that improve productivity. The catchment conservation measures also build resilience, enhancing communities' ability to adapt to climate change.

Over 40 water funds are now in operation worldwide, in 13 different countries, all involving The Nature Conservancy. The water fund model has been particularly successful in Latin America where it originated with the first fund being implemented in Quito, Ecuador in 2000. Most Water Funds have been established where there is market failure in that the price of water does not reflect the true costs (including environmental and resource costs) of delivering clean water, or where there has been a need for improved coordination of public and private sector actors through a collective platform[5]. The first of these water funds in

[5] TNC. 2018. Greater Cape Town Water Fund Business Case. Cape Town, South Africa.

Africa was the Upper Tana Nairobi Water Fund (UTNWF) in Kenya that now benefits a wide range of stakeholders and helps to meet water demands in Nairobi (see next section). The Greater Cape Town Water Fund followed in 2018, with a specific focus on restoring water source catchments affected by alien plant invasions. In addition to the two water funds that are up and running, a number of new funds are being initiated throughout Africa. Anchor Environmental Consultants has provided technical support in the feasibility and design stages for several of these funds.

PROOF OF CONCEPT: THE UPPER TANA-NAIROBI WATER FUND

The Upper Tana-Nairobi Water Fund was launched in 2015 to help protect and restore the quality and supply of water to the city of Nairobi, one of Kenya's most economically important regions. The Fund is now a registered Charitable Trust that is governed by an independent Board of Trustees through a public-private partnership with broad institutional representation from the private sector, public sector (including water, environment, and agricultural ministries), and nongovernmental organizations[6]. The Upper Tana-Nairobi Water Fund was initially capitalised with US$10 million, of which US$7 million was from the Global Environment Facility (GEF). Fundraising is ongoing to capitalise US$15 million endowment with investments from a wide range of beneficiaries and donors.

The Upper Tana River basin, covering 17 000 km^2 and home to 5.3 million people, provides critical hydrological services that are of importance to the Kenyan economy and the environment. It is the most productive basin for agriculture in Kenya, provides water to key national parks, generates significant amounts of hydropower, and supplies 95% of Nairobi's water[7]. However, deforestation and poor agricultural practices threaten the health of the catchment causing sedimentation problems, which has reduced the capacity of reservoirs and increased the cost of water treatment. The Upper Tana-Nairobi Water Fund was created to help address these problems by restoring ecosystem health in the basin through the financing of watershed conservation activities. The objectives of the Fund are to reduce sediment concentrations in rivers and reservoirs, increase revenues for hydropower generators, decrease water treatment costs, increase water yields, reduce water-borne diseases, and increase agricultural yields for smallholder farmers in upper catchment areas. While the main ecosystem services targeted through the Fund are water quality and water supply, co-benefits include increased agricultural output due to better soil management, increased incomes for farmers, employment opportunities, greater supply of fodder for livestock, new habitat for pollinator species, and carbon storage.

To date the following interventions have been implemented in the basin:

- Tree planting: 2.8 million high-value tree seedlings planted, 100 000 bamboo seedlings established, and 200 000 fodder shrub seedlings planted.
- Improved forest conservation and reforestation: 40 000 ha of public forest under improved conservation through community forest associations and targeted enrichment planting.
- Protection of riparian zones: fencing off, removal of cultivation, rehabilitation through enrichment planting, controlled livestock water points.

6 Vogl, A.L., Bryant, B.P., Hunink, J.E., Wolny, S., Apse, C. & Droogers, P. 2017. Valuing investments in sustainable land management in the Upper Tana River basin, Kenya. J. Environ. Manage. 195, 78–91.

7 TNC. 2015. Upper Tana-Nairobi water fund: A business case. Nairobi, Kenya.

- Sustainable land management: 78 400 ha of farmland under in-situ SLM, including mulching, minimum tillage, planting of grass strips, and terracing.
- Rainwater harvesting: 11 000 ha of water pans installed for on-farm rainwater harvesting, rural road runoff harvesting, and 3000 drip irrigation kits deployed.
- Extension services: full time staff, technical officers, technology interns and students provide much needed extension services and training to farmers in new farming practices.

The economic impacts of these interventions include:

- Farmer impacts:
- More than 25 000 farmers applying soil conservation and water-saving methods;
- Increased agricultural yields for smallholder farmers to the value of US$3 million per year;
- More than 8 500 coffee farmers certified for Rainforest Alliance; and
- More than 28 000 farmers enrolled in the mobile phone monitoring platform.

- Land and water impacts:
- 27 million more litres of water flowing to Nairobi each day;
- Over 50% reduction in sediments in rivers;
- Over 500 000 trees planted each year in the basin; and
- 196 000 acres of land under sustainable land management.

- Business impacts:
- Over US$600 000 increased annual revenue for Kenya Electricity Generating Company as a result of increased power generation and avoided shutdowns; and
- About US$250 000 cost savings per annum for Nairobi City Water and Sewerage Company as a result of reduced treatment costs.

The main challenge associated with the implementation and operation of the Upper Tana-Nairobi Water Fund has been in managing the expectations of beneficiaries[8]. Certain beneficiaries, particularly the water and energy utilities, while supportive of the Project, were reluctant to commit investments without more detailed analyses of the firm-level ROI and evidence of improved ecosystem service outputs. Managing their expectations required extensive stakeholder engagement and a dedicated participatory process to help build much-needed trust among stakeholders.

[8] Vogl, A.L., Bryant, B.P., Hunink, J.E., Wolny, S., Apse, C. & Droogers, P. 2017. Valuing investments in sustainable land management in the Upper Tana River basin, Kenya. J. Environ. Manage. 195, 78–91.

3 MOMBASA'S WATER SUPPLY SITUATION

CURRENT WATER SUPPLY NETWORK

Mombasa is home to 1.2 million people (KNBS, 2019a), making it Kenya's second largest city after Nairobi. Situated on the Indian Ocean coast, it is Kenya's foremost tourist city and is strategically located to service the country's interior through import and export of goods received through its port (Kithiia & Majambo, 2020). However, the city faces severe water supply challenges. Because the region lacks surface water resources, Mombasa relies primarily on groundwater and springs, with its main water sources being the Baricho Wellfield, Mzima Springs, Marere Springs and Tiwi Wellfield, with Baricho Wellfield and Mzima Springs (see Box 3.1) currently providing 58.1% and 32.3% of Mombasa's total water supply, respectively (Table 3-1). These water sources are situated at a considerable distance from the city (up to 220 km away in some cases), making the city dependent on an extensive bulk water supply network. Furthermore, all of Mombasa's key water sources also supply a number of other urban centers in the coastal region (Figure 3-1). The overall population served by the bulk water supply network is thus around 2 million (Rural Focus Ltd, 2020). Mombasa's water supply is estimated to be just one third of demand (Rural Focus Ltd, 2020). Compounding the issue, the city's population is growing rapidly, which is set to put further pressure on an already overstretched water supply system. Enhancing Mombasa's formal water supply is thus crucial to the future of the city.

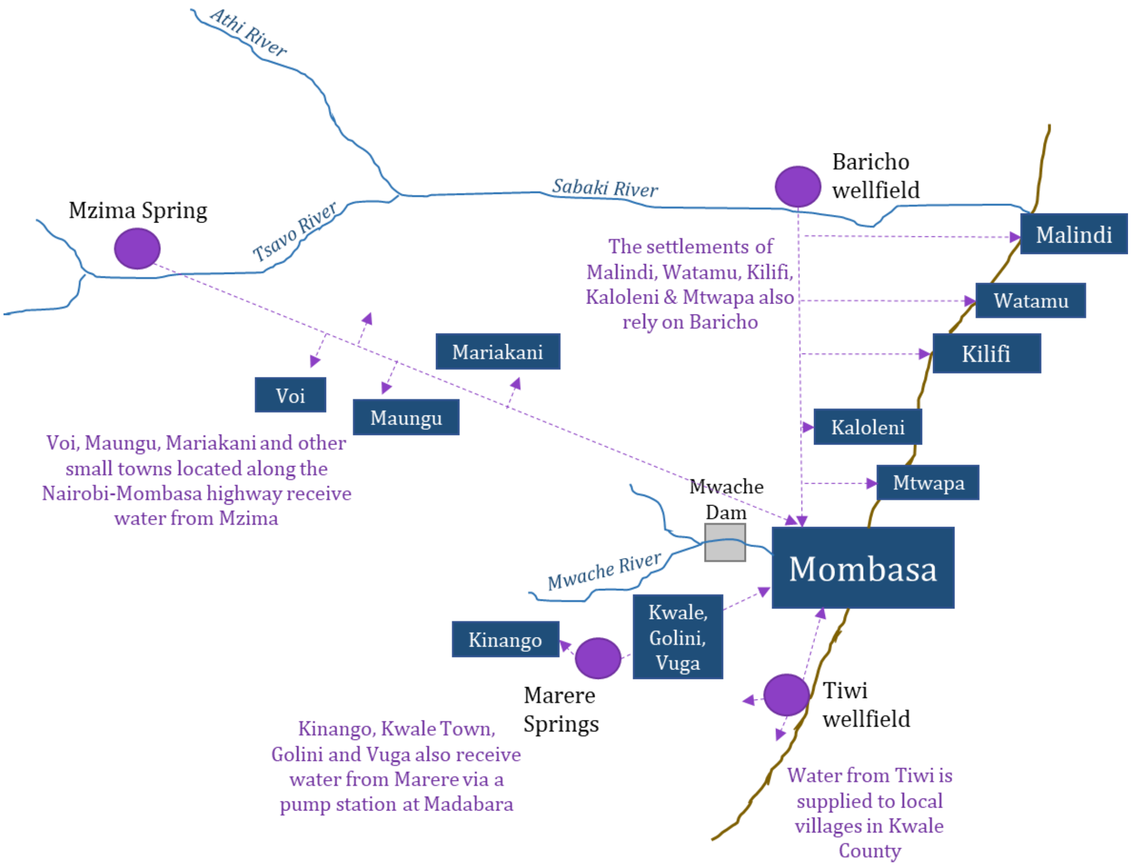


Figure 3-1. A simple schematic showing the water sources for Mombasa and the other large settlements, small towns and villages that receive water from these same sources. Note that Mwache Dam is still to be constructed and will supply water to Mombasa.

Box 3.1. The main water sources for Mombasa, Kwale, Kilifi and Taita Taveta Counties

Mzima Springs

Mzima Springs, located in Taita Taveta County, provides the second biggest water source. The Mzima Springs recharge area is estimated to cover between 2,126 and 2,141 km^2 (Rural Focus Ltd, 2020). The alluvial aquifer, the source of the springs, underlies the Chyulu Hills, a volcanic mountain range which stretches 100 km across Makueni County. A small part of the recharge area also extends into the counties of Kajiado and Taita-Taveta. The Chyulu Hills National Park covers the eastern portion of the hills covering 741 km^2. This adjoins the Tsavo West National Park to the southwest. The cloud forests of Chyulu Hills play a vital role in capturing rainfall and condensation (from mist) that then infiltrates into the underground aquifer. Millions of cubic metres of water are stored in the aquifer. This water flows southeast to where it emerges at the Mzima Springs, a series of natural springs situated within the Tsavo West National Park some 30 km away from the Chyulu Hills (Figure 3-2). Downstream of the large pools the outflow from the spring joins the Mzima River, a tributary of the Tsavo River, which flows into the Galana River (Wildlife Works Carbon, 2016).

The recharge area encompasses the Chyulu Hills and the lower plains to the northwest. Elevation ranges from 900 m above sea level to a maximum of 2,175 m above sea level at the peak of the Chyulu Hills (Wildlife Works Carbon, 2016). There is significant inter-year variation in the amount and timing of rainfall across the recharge area, varying from an average of 350 mm per annum in the lowland areas to 700 mm in the mountainous Chyulu Hills. Temperatures range from highs of 35 °C in February to lows of 20 °C in July (Wildlife Works Carbon, 2016). Water reaches Mombasa via a 215 km pipeline, which transports water to the Mazeras Reservoir (Rural Focus Ltd, 2020). Before reaching Mombasa, water is extracted from the pipeline by various settlements along the Nairobi-Mombasa highway, including Voi, Maungu and Mariakani. Due to rising demand from these settlements and deteriorating infrastructure, the amount of water reaching Mombasa from Mzima Springs has declined. Currently, only about 43% of water extracted at Mzima reaches Mombasa County (Rural Focus Ltd, 2020).

Across the lowland areas of the recharge area, savanna grassland and *Acacia-Commiphora* deciduous bushland are the dominant vegetation types. The volcanic mountainous area of Chyulu Hills is covered in lava forest and a dense, moist cloud forest.

Figure 3-2. The Mzima Springs situated in Tsavo West National Park. Source: Emily Le Cornu, AECOM; Luděk Fürst, Google Earth.

Baricho wellfield

The Baricho Wellfield is located in Kilifi County and consists of eight boreholes situated alongside the Sabaki (Athi) River. The site initially consisted of a surface water intake on the Sabaki River. However, subsequent studies revealed the presence of a paleochannel aquifer underlying the riverbed, which led to the development of the wellfield. The aquifer is hydrologically connected to the Athi-Galana-Sabaki River, which is almost entirely responsible for recharge of the aquifer, providing sufficient water to sustain existing abstraction quantities (Zamconsult, 2017). The aquifer has exceptionally high transmissivity[9] values of 7000 m^2/d at discharge rates in excess of 1000 m^3/hr (Rural Focus Ltd, 2020), resulting in high pumping capacity

[9] The ease with which water can move through fractures or pore spaces.

compared to most aquifers in Kenya. Water from the Baricho Wellfield is pumped to Mombasa via a pipeline to the Nguu-Tatu Reservoirs which have a capacity of 18 000 m^3 (Muhammed *et al.*, 2018). From there, water is transported to the Mombasa North Mainland through a gravity trunk line. The wellfield also provides the bulk of Kilifi County's water, including the coastal settlements of Malindi, Watamu, Kilifi and Mtwapa, as well as the inland settlement of Kaloleni. While Baricho is the biggest supplier of water to Mombasa, the high cost of pumping water to the city is a drawback of this water source (Rural Focus Ltd, 2020). Flooding of the wellfield has also been a serious issue on multiple occasions, damaging infrastructure and introducing iron-related bacteria into the water supply system.

Marere Springs
The Marere Springs are the oldest of Mombasa's major water sources, first developed in 1916 (Nyanchaga, 2016). They are located on the western flank of the Shimba Hills in Kwale County, and comprise three discrete spring units: the Marere, Voita and Mwaluganje. The contributing groundwater catchment and the springs themselves fall within the Shimba Hills National Reserve. The geology of the contributing catchment is mostly made up of Mazeras sandstones of late Triassic to early Jurassic age. The contributing catchment is relatively small in size at 10.57 km^2 in area. The presence of the Shimba Hills Natural Reserve offers the catchment area a level of protection, with much more intact natural vegetation relative to the farming areas surrounding the reserve. Vegetation in the contributing catchment comprises a mix of forest and grassland, due in part to historical deforestation activities (Schmidt, 1992; Rural Focus Ltd, 2020). Water from the springs is transported to Mombasa by a pipeline which terminates in the Changamwe reservoir which has a capacity of 30,000 m^3 (Rural Focus Ltd, 2020). Water from the springs is also transported to the towns of Kwale, Golini and Vuga via a pumping station at Madabara.

Figure 3-3. The Shimba Hills National Park in Kwale. Photo: Jane Turpie

Tiwi Wellfield
The Tiwi Wellfield is located in Kwale County to the south of Mombasa, about 4 km west of the Indian Ocean coastline. The Tiwi aquifer is semi-confined to confined and comprises of a mixture of coarse sandy fluvial, deltaic and littoral sediments, which have been termed as Pleistocene Kilindini Sands (Rural Focus Ltd, 2020). The Kilindini Sands at Tiwi are among the highest groundwater yielding sedimentary formations in Kenya (Oiro & Comte, 2019). The exact boundaries of the aquifer are not known. However, there is a distance of 5.7 km between the northern and southernmost boreholes in the wellfield. The eastern boundary of the aquifer abuts Pleistocene fossil coral limestones, while its poorly defined western boundary abuts the Pleistocene Magarini Formations. While the exact size of the aquifer is unknown, the most recent estimates suggest the recharge area is about 40 km^2. Estimates of the annual recharge of the Tiwi aquifer range from 30 000m^3/d (Adams, 1986) to 38,400 m^3/d (MWC&PC, 1994). Recharge is thought to come from the seasonal swamps and ephemeral streams found within the catchment. Assuming that sustainable yield is about 50% of mean annual recharge suggests the maximum safe amount of extraction from the aquifer would be 19,200 m^3/d (Rural Focus Ltd, 2020). This suggests some scope for expansion of abstraction of boreholes in the wellfield, which currently have a combined design capacity of 13,000 m^3/d. In addition to supplying Mombasa, the Tiwi aquifer is an important source of water for local villages in the coastal region. The location of boreholes as close as 2.9 km from the coast suggest a risk of saltwater intrusion. Indeed, there is evidence for recent saltwater intrusion into parts of the Tiwi aquifer, which presents a challenge for its future sustainability as a water source.

Table 3-1. Current water sources for Mombasa. Source: Rural Focus Ltd, 2020; Aurecon, 2020

Water source	Location	Design capacity (m^3/day)	Existing use (m^3/day)	Supply to Mombasa 2018 (m^3/day)	% of Mombasa's total supply
Baricho Wellfield	Southern bank of the Sabaki River 100km north of Mombasa	95 000	83 000	27 000	58.1%
Mzima Springs	In Tsavo National Park 220 km northwest of Mombasa	35 000	35 000	15 000	32.3%
Marere Springs	Shimba Hills 45km southwest of Mombasa	12 000	8 000	2 500	5.4%
Tiwi Wellfield	Tiwi 20km south of Mombasa	13 000	13 000	2 000	4.3%
Total		**148 000**	**139 000**	**46 500**	

WATER SUPPLY CHALLENGES

Due to upstream abstraction, inefficient pumps and leakages along the extensive pipe system, Mombasa receives about a third of the system's design capacity for bulk water supply, around 46 500 m^3/day (Rural Focus Ltd, 2020). This water is supplied to Mombasa by the CWWDA at cost (Ksh20/m^3)[10], which the city then sells to users using stepped pricing (the more used, the higher the tariff). Within Mombasa, the water reticulation and metering system is also old and dilapidated, resulting in further leakages and substantial losses, so that only about 53% of water is paid for by users. Furthermore, the supply to users is intermittent (certain days of the week), and the quality is unsuitable for drinking (Kithiia & Majambo, 2020).

The water supplied to Mombasa is considerably less than that leaving the springs and boreholes, largely due to the lack of maintenance of pumps and leakages along the very long network of pipes required to deliver the water from the source areas (104 km from Baricho Wellfield and 215 km from Mzima Springs). Ageing infrastructure and insufficient maintenance mean leaks are frequent, resulting in substantial losses of water. Pumps at the water source areas also often fall short of design capacity due to inefficiencies and breakdowns. For example, the Baricho pumping system broke down twice in 2017, cutting off water supply to a number of customers in Mombasa (Rural Focus Ltd, 2020). Although Mombasa receives an official allocation of 46 500 m^3/day, leakages and inefficiencies mean the amount of water reaching Mombasa in reality is around 35 000 m^3/day at best on a good day (Anthony Njaramba, MOWASSCO, pers. comm.).

Similar infrastructural challenges occur once water reaches Mombasa. The city's piped water system is old and in urgent need of rehabilitation. Corrosion and dilapidation have resulted in contamination of the city's supply network by stormwater and sewage[11], while leakages result in substantial water losses (Kithiia & Majambo, 2020). Poor metering and widespread failure to pay water bills[12] also erode the financial viability of the Mombasa water service provider

[10] US$1 ~ Ksh100 000 in 2021; Ksh20/m^3 = Ksh20 000/ML = US$0.05/ML

[11] There is no sewage reticulation or treatment facility at all in Mombasa. Toilets drain into soakaways, which means that sewage infiltrates into the ground.

[12] MOWASSCO's Director stated that the payment rate of bills has increased to 94%; however, he also stated that new meters had not been installed for years, so many users are unmetered.

(MOWASSCO), adding to the challenges of maintaining the city's water supply system. Due to dilapidated infrastructure and unpaid bills, Mombasa suffers from a high level of non-revenue water (NRW) at 47%. This is well above international best practice levels of 20-25%, and also exceeds the NRW average for East Africa, which stands at 41% (Kithiia & Majambo, 2020).

Mombasa's inhabitants address the shortfall in the city's formal water supply using private boreholes (often illegally installed; Rural Focus Ltd, 2020), hand-dug wells or purchasing water from bowsers (Figure) and vendors. Drilling boreholes is costly and does not always result in potable water, while water from bowsers is several times more expensive than water provided by MOWASSCO, placing a severe burden on the city's poorer residents. Furthermore, the proliferation of unregulated boreholes has resulted in widespread salinization problems given the city's coastal location resulted (Kithiia & Majambo, 2020). Notably, 94% of borehole water samples taken from across Mombasa's North Coast were found to exceed WHO salinity limits, rendering unsuitable for drinking without costly treatment (Idowu, Nyadawa & K'Orowe, 2017). Additionally, Mombasa effectively lacks a sewage system, forcing residents to rely on soakaways. This in turn contaminates borehole water, presenting a serious health risk. Boreholes thus do not provide a satisfactory solution to the city's water supply woes, particularly as water table drawdown and salinization will worsen with continued abstraction.

Figure 3-4. A water bowser delivering water in an affluent neighbourhood of Mombasa. Photo: LJ Wilson

PLANNING FOR GROWING DEMANDS AND SCARCITY

Water scarcity is already a serious problem in the Coast region. In 2012, urban water demand from towns served by the bulk water system was estimated to be 211 000 m^3/day, and projected to rise to 296 000 m^3/day by 2020 (Tahal Group, 2013). This is more than double the current system-level supply estimate of 139 000 m^3/day, indicating a major supply shortfall. The supply shortfall experienced by Mombasa is even more severe than this. The extensive, unmonitored use of private boreholes and bowsers makes it difficult to estimate Mombasa's water demand precisely (Kithiia & Majambo, 2020). In 2018, demand for water in Mombasa was estimated to be 155 840 m^3/day in 2018, with about 80% being for domestic use and 20% for industrial use (Rural Focus Ltd, 2020). A more recent estimate of demand is 200 000 m^3/day (Kithiia & Majambo (2020), which matches the estimate obtained from consultation with MOWASSCO (Njaramba, pers. comm.) The official water allocation of 46 500 m^3/day to Mombasa is only a third of the demand estimate provided by Rural Focus Ltd (2020), and a quarter of the demand estimate reported by Kithiia & Majambo (2020) and Njaramba (pers. comm.). The supply shortfall becomes even more severe if using the realistic supply estimate of up to 35 000 m^3/day provided during consultation with MOWASSCO (Njaramba, pers. comm.). If using this supply estimate in conjunction with the 200 000 m^3/day demand estimate, formal water supply amounts to just 17.5% of demand in Mombasa, and this is on a "good day".

Mombasa's population is growing rapidly, which is set to put further pressure on its already overstretched water supply system. Water coverage in Mombasa was reported to decline from 54% to 43% between 2015/16 and 2016/17 (Rural Focus Ltd, 2020), indicating water supply capacity is already falling further behind demand. By 2035 Mombasa is projected to have almost 2.3 million people and demand is expected to increase to 317 715 m^3/day (Rural Focus Ltd, 2020). Over the same period, the population across Mombasa and the coastal towns that share bulk water supply areas with the city is expected to rise to 4.4 million, with a water demand of 531 045m^3/day. In addition to worsening water shortages in Mombasa, population growth in the broader coastal region could lead to increasing competition for scarce water resources between Mombasa and other regions which form part of the bulk water supply network.

Given that existing water supply deficits are already serious and likely to become even more severe in the future, expansion of Mombasa's water supply is a key priority for the city. A number of expansion plans currently exist, involving both the augmentation of existing water sources and the development of new water sources. Plans for expansion of existing water sources include further expansion of groundwater abstraction at Baricho. According to the Mombasa and Coast Province Water Supply Master Plan published in 2013, abstraction from Baricho could be increased to 146 000 m^3/day (Tahal Group, 2013), a substantial increase from the current design capacity of 110 000 m^3/day. More recent engagement with CWWDA suggests potential abstraction at from Baricho is higher still, at around 180 000 m^3/day (Martin Tsuma, CWWDA, pers. comm). In any case, current extraction from Barico is around 100 000 m^3/day, which is 10 000 m^3/day less than design capacity (Tsuma, pers. comm.). Possibilities for augmentation of the water supply from Marere Springs have also been identified. However, the additional volume of water that could be supplied is small in relation to the size of Mombasa's water supply deficit (Rural Focus Ltd, 2020). Similarly, there is some additional capacity for future development of the Tiwi aquifer, though the potential supplement is again relatively small. Furthermore, saltwater intrusion into parts of the aquifer calls the sustainability of even the current pumping regime at Tiwi into question (Oiro & Comte, 2019).

Expansion plans at Mzima Springs involve the construction of a new pipeline, modified offtake structure and treatment facilities and additional break pressure tanks (Rural Focus Ltd, 2020). It is envisaged that this would increase abstraction from 35 000 m^3/day to 95 000 m^3/day, of which 50 050 m^3/day would be allocated to Mombasa. Once more, our engagement with CWWDA suggested even greater potential for expansion than these earlier estimates, with Tsuma (pers. comm) suggesting future plans are to extract 145 000 m^3/day from Mzima Springs, though the amount that would be allocated to Mombasa was not specified in this interview. Even if using the lower estimate, this would represent a sizeable addition to Mombasa's water supply, effectively doubling the existing formal supply. This development will likely be the next major augmentation to Mombasa's water and could come online within a year or two if construction is done efficiently (Njaramba, pers. comm).

The planned Mwache Dam (Figure 3-5) is set to become the biggest source of water to Mombasa. Estimates of the potential storage capacity of the dam vary from 120-136 MCM/year (Rural Focus Ltd, 2020). Based on a supply capacity estimate of 370 000 m³/day, it is projected that 186 000 m³/day will be supplied to Mombasa. This exceeds the combined design capacity of all of Mombasa's existing water sources and is more than triple the existing amount of water supplied to Mombasa. The Mwache Dam thus promises to provide a massive increase in water availability for the city. A contract for the construction of the dam has been issued and construction is expected to commence before the end of 2021 (Eng. Kiprotich, CDA, pers. comm) and reach completion within six to eight years (Njaramba, pers. comm).

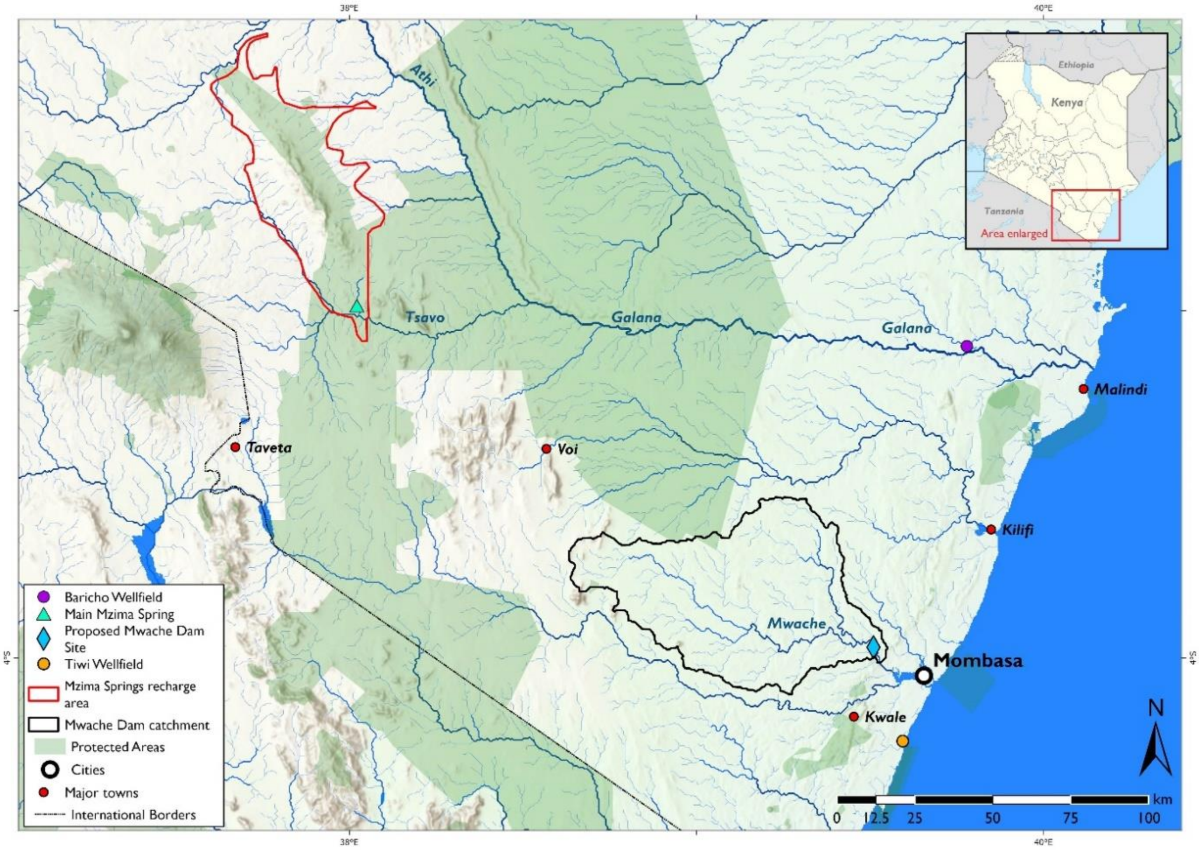


Figure 3-5. The Mwache Dam catchment and Mzima Springs approximate recharge area as key components of the Mombasa water supply system, which currently comprises the springs and wellfields shown.

Other major expansion plans include the construction of desalination plants. Current plans are for the construction of two plants with a combined capacity of 130 000 m³/day, all of which could be supplied to Mombasa (Rural Focus Ltd, 2020). This plan was confirmed in a meeting with the Mombasa County Government. However, desalination could cause considerable damage to the sensitive coastal environment around Mombasa. Furthermore, desalination will be costly. Despite reduction in the cost of desalination in recent years, it still often ranks as the most expensive water supply option (World Bank, 2019). Tahal Group (2013) estimated the water price at the desalination plant gate to be US$1.45/m³, though desalination costs have declined since this study was done. For example, World Bank (2019) estimates the total cost of water production using seawater reverse osmosis (SWRO) typically ranges from US$0.72-US$1.20/m^3. These lower recent cost estimates are still much higher than the CWWDA's current bulk water charge of Ksh20/m^3 (about US$0.20/$m^3$) (Tsuma, pers. comm.), raising serious questions about the financial suitability of desalination plans.

Increasing water supply to Mombasa will unlock considerable development potential. However, to do so, the infrastructure shortcomings within Mombasa also need to be addressed. In this regard, there are projects aimed at improving the water supply system within Mombasa. For example, the World Bank and AFD are funding projects to improve the water reticulation system in Mombasa (Njaramba, pers. comm). In some places, this requires completely replacing the existing infrastructure. The nature of World Bank funding is also providing incentives for WSPs to reduce leakages, as they are providing support in the form of loans which will be converted to grants once WSPs reduce non-revenue water losses (Tsuma, pers. comm).

THREATS POSED BY DEGRADATION OF WATER SOURCE AREAS

While the construction of the Mwache Dam and increasing capacity of the Mzima Springs, in particular, will greatly alleviate Mombasa's water shortages, the projected flows could be relatively short-lived if environmental problems in the source areas are not addressed. Reduction of vegetation cover in the Mwache Dam catchment will lead to high levels of sedimentation and reduced water quality in the Mwache Dam, and in the Mzima Springs Recharge Area will reduce the infiltration of rainfall into the groundwater that feeds the springs. Within the Mwache Dam catchment, a number of human activities increase the risk of soil erosion (Mburu, Kung'u & Muriuki, 2015; RTI International, 2017), including:

- Lack of soil conservation measures in cultivated areas, which is particularly problematic in more hilly areas which are naturally more prone to erosion. Large areas of arable land are bare during dry periods, resulting in a high risk of erosion by wind or rain;
- Clearing of vegetation in riparian zones to make way for cultivation, which has occurred across much of the catchment, and which substantially increases the export of sediment into watercourses (Figure 3-6).
- Overgrazing;
- Deforestation for fuelwood and building materials; and
- Quarrying and sand harvesting along and within watercourses, which also contributes to riverbank collapse.

Water samples from the lower catchment reveal consistently high levels of total suspended solids, providing evidence that heavy erosion is occurring in the catchment due to the various land use practices mentioned here.

Figure 3-6. Erosion in the lower Mwache Dam catchment. Photo: JK Turpie

In addition to high sedimentation, water resources are threatened by poor sanitation practices. A sizeable proportion of households in the catchment lack any form of toilet facilities (ESC, 2018a). Open defecation is thus widely practiced, signifying a serious threat to human health, particularly in more densely populated parts of the catchment.

PRIORITY AREAS FOR CONSERVATION INTERVENTIONS

Two priority areas have been identified for conservation interventions: the Mwache Dam catchment area, and the Mzima Springs Recharge Area. These are set to become the major future water sources for Mombasa, supplying approximately 47% and 19% of the city's water, respectively (Tahal Group, 2013). The projected water supply to Mombasa once the Mwache Dam and upgrading of the Mzima Springs infrastructure are completed amounts to 313 000 m^3, several times greater than the current supply of 46 500 m^3/day (Rural Focus Ltd, 2020). In addition to significantly increasing water availability for Mombasa, the supply of water from Mwache Dam and Mzima Springs would reduce Mombasa's demand for water from the Baricho Wellfield, Tiwi Boreholes and Marere Springs. This would allow more water to be supplied form these sources to other areas in the bulk water supply network, thus alleviating water shortages in the broader region too (Rural Focus Ltd, 2020).

While the construction of the Mwache Dam and augmentation of Mzima Springs hold much promise for enhancing Mombasa's water supply, the long-term sustainability of these water sources is threatened by a range of activities. The protection and management of the contributing catchments for the Mwache Dam and Mzima Springs is thus of the utmost importance to the future of Mombasa and surrounding areas. The threats faced by these water source areas and their importance to Mombasa's future water supply make them the priority areas for investments in nature-based solutions.

4 RECENT ADVANCES TOWARDS IMPROVING WATER SECURITY

KENYA WATER SECURITY AND CLIMATE RESILIENCE PROJECT-2

The Mwache Dam is being constructed as part of the World Bank "Kenya Water Security and Climate Resilience Project - Phase 2 (Coast Region)" (KWSCRP-2), which aims to sustainably increase bulk water supply to Mombasa County and Kwale County, and to increase access to water and sanitation in Kwale County. The KWSCRP-2 is being executed by the Coast Development Authority (CDA). The components of this project are summarised in Figure 4-1.

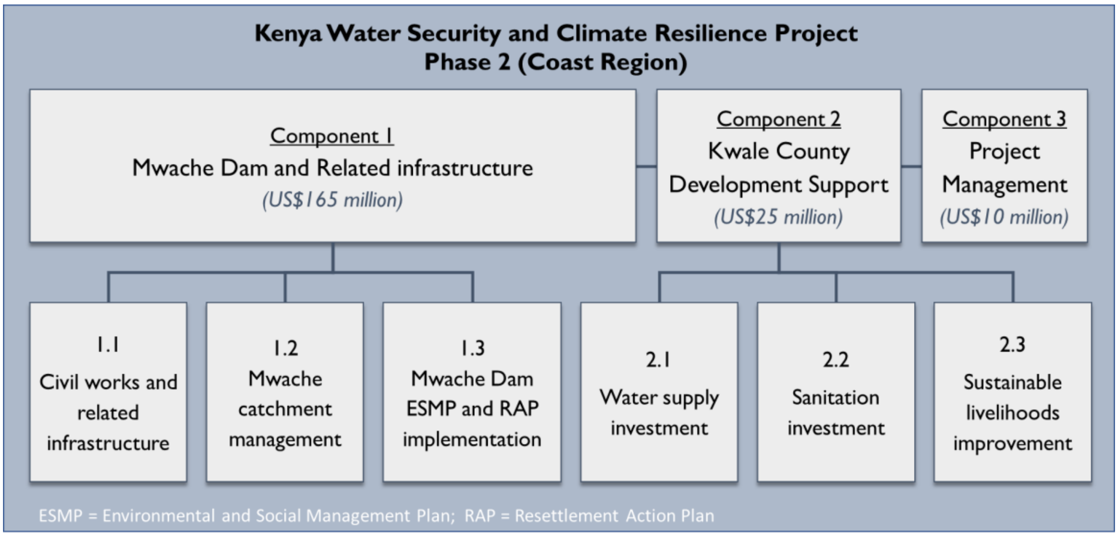


Figure 4-1. Components and subcomponents of the Kenya Water Security and Climate Resilience Project - Phase 2, Coast Region (KWSCRP-2)

Sub-component 1.1 finances the construction of the main dam (Mwache), one check dam (lower check dam), raw water transmission lines to the water treatment plant, transport infrastructure (roads), electro-mechanical equipment and buildings, and a 100 ha irrigation pilot scheme.

CONSIDERATION OF CATCHMENT DEGRADATION IN MWACHE DAM DESIGN

As part of the dam design activities under sub-component 1.1, Japanese firm Nippon Koei produced the "Design Review, Detailed Design and Construction Supervision for Mwache Multi-Purpose Dam" in 2018 (hereafter the Detailed Design Report). Sedimentation management is described in Chapter 3 of this report (see Nippon Koei, 2018). The report provides detail on the sediment balance of the system, including estimates of the mean annual sediment volumes to be removed from the upper and lower check dams and the total volume of sediment to be accumulated in the reservoir (Nippon Koei, 2018). The report identifies potential sites for sediment spoil bank areas and estimates the annual sediment removal costs from the sediment check dams.

To deal with the high rate of sedimentation expected from the Mwache Dam catchment area, the dam design includes two large sediment check dams to capture sediments before they enter the main reservoir in order to extend the lifespan of the Mwache Dam to 100 years (Figure 4-2). Their study estimated that the check dams would need to be evacuated continuously using a large fleet of trucks, at a total annual cost of about $8 million per year (Nippon Koei, 2018) and confirmed through consultation with a CDA engineer. This does not count the large area that would need to be set aside to receive this spoil. The cost of clearing the check dams is not covered by the KWSCRP-2 funds (Eng. Kiprotich, CDA, pers. comm.). However, without this, the lifespan of the Mwache Dam would be only 20 years.

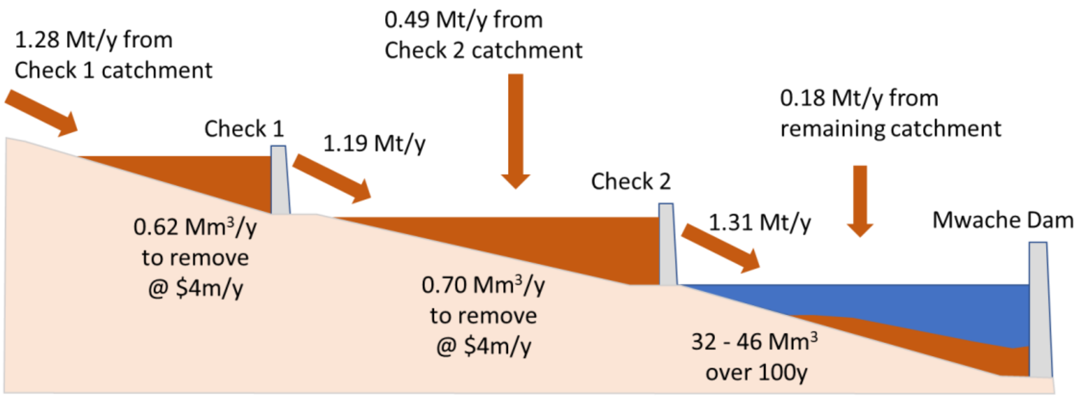


Figure 4-2. Schematic of the movement of sediment into and between check dams and the Mwache dam, and the estimated rate and cost of excavation from the check dams, based on Brune's Method. Source: diagram adapted from Nippon Koei (2018).

KWSCRP-2 ACTIVITIES RELATING TO CATCHMENT MANAGEMENT

Recognising the importance of catchment interventions, the aim of KWSCRP-2 Sub-component 1.2 is to improve the sustainability of the Mwache water supply system through the integration of a set of watershed conservation and livelihood interventions. This is being done under the CDA's Mwache Catchment Management Project. Seven activities were laid out under the Mwache Catchment Management Project, including:

- Activity 1a. Physiographic Study (geomorphology, erosion hotspots, Watershed Management Interventions Plan) – completed 2017;
- Activity 1b. Options Study for sustainable management and conservation of Mwache Catchment (local livelihoods, intervention options, and recommendations for implementation of payments for ecosystem services) – completed 2018;
- Activity 2. Sub-catchment Management Plans (formation of WRUAs, development of sub-catchment management plans, WQ monitoring, sand harvesting legislation;
- Activity 3. Catchment management WRUA support (afforestation, reforestation, conservation works, gabions, pegging riparian areas) (800 of 2000 ha as at 2020); and
- Activity 4. Communication and training in watershed conservation.

Activity 3 of the Mwache Catchment Management Project appears to have commenced ahead of the sub-catchment management plans (SCMPs). The performance indicator for these activities is the target area (in hectares) where land and water management practices have been adopted as a result of the project (see Table 4-1). A target of 2000 ha had been set, to be completed by 2022 (Coast Development Authority, 2020a). Some 780 ha had been treated by September 2020 (see Coast Development Authority, 2020a, 2020b), and is still ongoing (Dickens Riungu, CDA, pers. comm.). Spatial data on where these interventions have been planned or carried out are not available.

Table 4-1. Results Framework used to monitor implementation of interventions as part of the Mwache Catchment Management Project. WRUA = Water Resources Users Association, SCMP = sub-catchment management plan. Source: Coast Development Authority, 2020a, 2020b.

Indicator	**Unit**	**Baseline**	**2015/16**	**2016/17**	**2017/18**	**2018/19**	**2019/20**
Target area	**ha**	**0**	**0**	**0**	**200**	**500**	**800**
Achieved (cumulative)	ha	0	0	202	461	601	780
A1 Afforestation	ha	0	0	57	178	185	276
A2 Terraces & gabions	ha	0	0	70	172	229	283
A3 Marking of riparian areas	ha	0	0	75	111	187	221
Target WRUAs formed	No.	1	24	24	24	24	24
Achieved (cumulative)	No.	1	24	24	24	24	24
Target SCMPs developed	No.	0	0	8	8	12	16
Achieved (cumulative)	No.	0	0	5	5	9	12

PHYSIOGRAPHIC STUDY

The Physiographic Study (RTI International, 2017) identified erosion hotspots and suggested possible remediation measures. Using the Revised Universal Soil Loss Equation (RUSLE) and the Land Degradation Surveillance Framework (LDSF), the study mapped the rates of soil erosion and classified areas as being low, moderate, high or very high. The report identified a number of "hotspots", although did not define the criteria for a hotspot.

The findings were summarised for each of the 21 sub-catchments of the catchment area (see example in Figure 4-3). For each sub-catchment, the types of activities that would be needed in each area were described, although the location of interventions and their extent were not given.

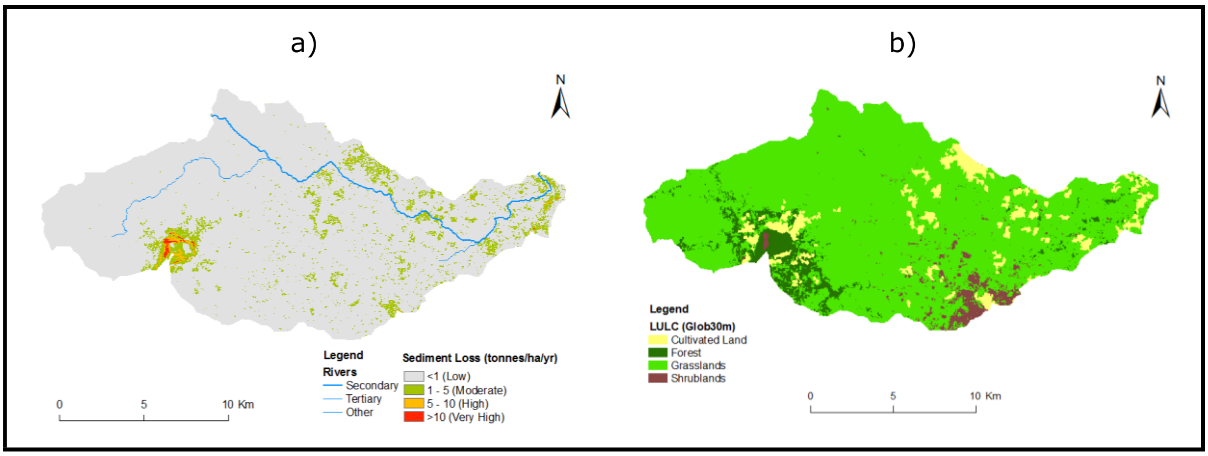


Figure 4-3. Example one of the sub-catchment spatial outputs of the Physiographic Study.

The areas with moderate, high or very high rates of erosion made up about 11.6% of the total area of the Mwache Dam catchment (just over 26 000 ha). Different types of interventions were suggested for the affected cropland, grassland, forest and shrubland areas (Table 4-2). The overall cost of these interventions was estimated to be US$30.4 million. The 2020 Progress Report for the Mwache Catchment Management Project identified that its planned activities and budget were not adequate to cover all the identified hotspots in the catchment, and that additional funding would be required.

Table 4-2. Summary of extent and costs of sustainable land management interventions for Mwache Dam Catchment in each of the four land cover types[13]. Source: RTI International, 2017.

Land Cover	Area Coverage (ha)	Interventions	Approximate Area Covered (ha)	US$	
				Cost/ha	Total Cost
Cropland	24 284	Conservation agriculture	1 982	550	1 090 100
		Agroforestry	1 982	651	1 290 282
		Household ponds	991	850	842 350
		Terraces	353	1 950	688 350
Grassland	323 954	Water pans	94	30 000	2 844 150
		Small earth dams	216	20 000	4 334 000
		Micro-/macro-catchments	9 699	1 600	15 519 680
		Grass strips	9 699	330	3 200 934
Forest land	10 581	Drylands forestry management	721	850	613 105
Shrubland	5 977	Farmer-Managed Natural Regeneration (FMNR)	421	20	8 436
Total	**364 797**		**26 162**		**30 431 387**

SUB-CATCHMENT MANAGEMENT PLANS

The erosion hotspot maps and qualitative recommendations on sub-catchment conservation interventions from the Physiographic Study are being used to develop the individual Sub-Catchment Management Plans (SCMPs). These each have their own catchment and riparian conservation targets and associated work plans and budgets (see Table 4-3 for an example).

While some detail on the location and extent is given for each sub-activity, these are not mapped out spatially in any detail. So far, SCMPs have been developed for14 of the 24 WRUAs (Mwanasiti Bendera, CWWDA, pers. comm). These are also being completed under the Mwache Catchment Management Project. The SCMPs are working documents for the Water Resource Users Associations (WRUAs) to address water resource management issues effectively. The targets and budgets for the SCMPs cover the next ten years. It does not seem that financing has been secured for the planned activities in the SCMPs, with some stating that the resources required to achieve outcomes are "yet to be mobilised" (e.g. Nyongoni WRUA, 2018).

[13] It is important to note that the land cover used in this study (Globeland 30m 2010) classifies most of the catchment area as being grassland, whereas most land cover datasets do not do so, and neither does this concur with the natural vegetation of the area as observed in the site visit.

Table 4-3. Activity plan and budget for catchment and riparian conservation for the Marenje WRUA, Source: (Marenje WRUA, 2018). In 2018, 1 US$ = 101.9 Kshs.

CH 8: Catchment and Riparian Conservation				
Target		Restore degraded riparian and catchment areas by planting trees and prohibiting destructive farming		
Output		Report on rehabilitated catchment areas and restored riparian zones		
Activity		Sub-activity	Budget (Kshs*1000)	Year
8.1	Riparian and Catchment restoration and conservation	8.1.1 Establish tree nurseries (1 per zone)	3000	Year 3-5
		8.1.2 Tree planting activities along riparian and degraded lands (50 square kilometre along riparian, both banks), Plant in three Wetlands, 1 per zone	4000	Year 4-9
		8.1.3 Introduce energy saving Jikos[14] (Total of 300, with 100 in each zone)	2000	Year 3-9
		8.1.4 Construct 12 areas of soil gabions (4 per zone) and establish 12 demonstration farms for terracing (4 per zone)	10 000	Year 4-8
		8.1.5 Monitor and evaluate progress	3000	Year 4-10
TOTAL			**21 000**	

OPTIONS STUDY ON CATCHMENT MANAGEMENT INTERVENTIONS AND PES

The Options Study for Sustainable Management and Conservation of Mwache Catchment (ESC, 2018a) was another output of the CDA Mwache Catchment Management Project. This study was tasked with:

- assessing the potential impacts of different interventions on soil erosion,
- describing the socio-economic characteristics of the catchment population based on a household survey,
- identifying priority management options, and
- coming up with a design for a payments for ecosystem services (PES) scheme to finance the priority interventions.

The first task was carried out using the Soil and Water Assessment Tool (SWAT), and the results were reported for a few selected sub-catchment areas (out of a total of 27 in this model). The assumptions regarding interventions were not laid out. Agroforestry, grass strips, and grass in waterways were mentioned, but the interventions appear to have been modelled as very broad changes in land cover (e.g. agriculture to forest). The model outputs were used to conduct a high-level estimation of water treatment cost savings and avoided costs of sedimentation to illustrate the benefits that could potentially be realised.

The socio-economic description was based on a survey of just under 500 households across the entire catchment. This survey provides a very useful profile of the population, which could be used in conjunction with census data. The study found the catchment area to be inhabited predominantly by Duruma-speaking people (95%) who have very low levels of education and live a very traditional way of life. People mainly live off a combination of crops and livestock, are highly dependent on collection of fuelwood and rely (by preference) on natural medicines. The study confirmed that land degradation is being driven by poor farming practices, wood

[14] Jikos are energy efficient woodfuel cook stoves.

fuel harvesting and charcoal production, but also that people are not aware of how their livelihood practices lead to land degradation.

The study listed and described similar interventions to those listed in the Physiographic Study but also included other developmental interventions to address poverty. Following the Physiographic Study, it was recommended that integrated catchment management should take place at the sub-catchment scale, through the WRUAs, and a Sub-Catchment Management Options Implementation Plan was developed (see Annex III in ESC, 2018). This lists a range of specific activities by activity area and work package over a two-year period (see summary in Table 4-4). Those responsible for leading and supporting the implementation of the activities are listed as *TBA* in the plan and the sites being targeted are all the sub-catchments within Mwache Dam catchment. The implementation plan for year two does list the targeted number of farmers, demonstration sites or WRUAs for each activity, but the individual activities do not include specific details on scale or location within each of the sub-catchments. There are no spatial maps attached to the plan.

Table 4-4. A summary of the three work packages, their activity areas and the year in which they are implanted as per the Sub-Catchment Management options implementation plan outlined in the Options Study for Sustainable Management and Conservation of Mwache Catchment, Source: ESC, 2018. FMNR=Farmer-Managed Natural Regeneration.

Work package	Activity Area	Year 1	Year 2
WP 1: Sub catchment-level natural resource management	1.1: Sub-catchment Action Plan (SCAP) development	X	X
	1.2: Sub-catchment capacity development for local institutions	X	X
	1.3: Sub-catchment level FMNR and enrichment planting	X	X
	1.4: Establishment and maintenance of water buffering	X	X
	1.5: Resource leveraging for water buffering infrastructure	X	X
	1.6: Protection and rehabilitation of denuded lands		X
WP 2: On-farm Water & Soil Management	2.1: On-farm rainwater harvesting	X	X
	2.2: Agroforestry and on-farm FMNR	X	X
	2.3: Soil conservation and fertility management	X	X
	2.4: Small-scale Irrigation		X
WP 3: Agricultural commodity production	3.1: Promotion of climate smart production for food security		X

Much of the Options Study focused on the potential for implementing a PES scheme in the Mwache Dam catchment. This included a review of the legal and institutional frameworks for PES in Kenya, with the following key findings:

- There is no PES-specific legislation relating to watershed protection in Kenya. However, there are some provisions that can be interpreted to lend support to PES through International law and the Constitution of Kenya;
- Capacity gaps exist within the current institutional framework which need to be strengthened before a PES scheme is implemented in the catchment. Shortfalls can be achieved through enhancement of existing institutions, rather than through the creation of new institutions; and
- Land tenure in the catchment presents a significant challenge to PES implementation, with the majority of people living on privately owned land not having secure land titles, and those living on communal land, the necessary regulations needed to operationalize the Community Land Act have not yet been passed (ESC, 2018a).

Following a literature review, from which information on a large number of PES schemes was summarised, the study proposed two possible PES scheme designs for the Mwache Dam catchment (ESC, 2018a):

- a public payment scheme through which government pays land managers to enhance ecosystem services on behalf of the wider public, or
- a public-private partnership payment scheme that uses both government and private funds to pay land or other resource managers for the delivery of ecosystem services.

The study recommended the use of a Trust which would "operate as a legal entity in perpetuity for the sole purpose of funding soil and water conservation activities within Mwache Dam catchment" (ESC, 2018a). It was recommended that a Board of Trustees manage the overall operations comprising of representatives from major stakeholders, for example County Governments of Kwale and Mombasa, Water Resource Users association, CDA, WRA among others (ESC, 2018a). To ensure sustainability of the fund, it was also recommended that it be a hybrid fund consisting of an endowment fund where capital is invested to generate a steady stream of income from the investment, and a revolving fund which is replenished through fees and/or donor contributions. Finally, it was recommended that the main implementing agent of the interventions as part of the PES scheme be undertaken by the WRUAs in the catchment.

DESIGN OF A PES INTERVENTION FOR MZIMA SPRINGS RECHARGE AREA

Efforts have already been made to address forest and rangeland degradation problems in the recharge area through the establishment of a REDD+ Project by the Chyulu Hills Conservation Trust[15] in 2013. While the project has already generated $12 million from the sale of carbon credits, and is expected to generate another $30 million in its next phase (Chris White, pers. comm.), financial analysis suggests that further income streams are needed to achieve the level of conservation required (GNIplus, 2021). The addition of payments for hydrological services to the revenue stream (which also includes ecotourism, philanthropy and government support) would help to achieve this, as well as helping to smooth funding flows.

The MWF could contribute to the successful protection of the geohydrological functioning of the recharge area through transfers to the Chyulu Hills Conservation Trust. The Project Area covers about 4100 km^2, of which the Chyulu Hills Water Tower[16] makes up a quarter. This would help the Trust to provide a steadier flow of payments and support to communities in return for conservation action.

---

15 Nine stakeholder partners make up the Chyulu Hills Conservation Trust. Six of the partners have title to all the land in the REDD+ project area. This is made up of Chyulu Hills National Park and a section of Tsavo West National Park, gazetted to KWS; the Kibwezi Forest Reserve titled to KFS; and four communally owned Maasai Group Ranches (Kuku, Kuku A, Imbirikani, and Rombo). The other three Trustee partners are the local NGOs: The Sheldrick Wildlife Trust, Maasai Wilderness Conservation Trust, Big Life Foundation.

16 Kenya's main water source areas are called Water Towers. The Chyulu Hills Water Tower encompasses the Chyulu National Park, Tsavo West National Park, Kibwezi Forest Reserve and Mbirikani and Kuku Group Ranches. It, traverses Makueni, Taita Taveta and Kajiado Counties. It covers 110 945 ha, of which about 7 895 ha is protected (Kenya Water Towers Agency, 2020).

IMPLICATIONS FOR THIS STUDY

The studies that have been carried out under KWSCRP-2 have provided significant insight into the unfolding water security situation. While the infrastructure projects are set to alleviate water security issues, it is clear from the Detailed Design Report, that the project still carries significant risk, with very large sums of money needed to maintain the required level of water delivery from the main asset being developed – the Mwache Dam.

In general, all of these studies have been carried out with very little data on the catchment area. Not only is there a paucity of rainfall and flow gauging data, but analysist have to rely on very low resolution, largely satellite-derived datasets on topography, land cover and soils, with very little ground-truthing. No environmental flow studies have been carried out. In addition, data on the population living in the intervention areas are scarce, apart from the 2019 Census. While this study suffered from similar limitations, it was clear that some aspects of the previous work needed synthesis and further investigation.

The Physiographic Study suggests a very high rate of sedimentation, but the catchment conservation activities funded under KWSCRP-2 fall well short of what is required. While the Physiographic Study provides an overall estimate of the type and extent of interventions required, this information was not presented in detail. The land cover data used in the Physiographic study were questionable, as were some assumptions about soil properties.

The Options Study makes an important contribution towards designing a payment mechanism for conservation interventions in the catchment area, but the assumptions of the workability of the proposed PES in the socio-economic and biophysical context of the study area needs further consideration. The Options study conducted a survey of 500 households throughout the catchment area, but the survey results reported in that study differed from the Census data and from our own observations in the study area.

The interventions suggested in the various studies, including the Sub-catchment Management Plans, are described in only very vague terms. Furthermore, the co-benefits of nature-based solutions and the impacts of sedimentation on water treatment costs, have not been considered.

This study therefore synthesizes and builds on the previous work to develop a more detailed plan and an economic case for the establishment of a Water Fund, as well as the organizational and financing mechanisms for the fund. We also consider the GNIPlus/AECOM study's proposed interventions for the Mzima Springs recharge area.

PART II. NATURE-BASED SOLUTIONS FOR WATER SECURITY

5 PROPOSED INTERVENTIONS FOR THE MWACHE DAM CATCHMENT

INTRODUCTION

This chapter develops a potential suite of interventions, taking into account their feasibility in terms of the biophysical characteristics of the study area, population characteristics, land tenure and land use, and their social acceptability. We begin by providing a description of the biophysical and socio-economic characteristics of the catchment, based on the analysis of more recent data than has been used in some of the preceding studies. We then review potential conservation interventions, providing a clear description of how they work, and under what circumstances they are effective. From this review and taking into account the findings of the Physiographic Study and the Options Study, we select suitable interventions as the focus of the proposed Water Fund. Finally, we use optimization modelling to narrow down the area required, so that interventions can be applied where the return on investment will be highest.

Figure 5-1. Well-managed farmland in a semi-arid region of Kenya. Photo by H. Liniger from Liniger *et al.*, (2011)

BIOPHYSICAL AND SOCIO-ECONOMIC CHARACTERISTICS OF THE CATCHMENT AREA

LOCATION AND EXTENT

The Mwache Dam catchment covers an area of 3560 km^2, most of which falls within Kinango subcounty of Kwale County (Figure 5-2). The western part of the catchment falls within Taita Taveta (Voi subcounty), while a small area in the northeast falls within Kilifi county (spread across Ganze and Kaloleni subcounties).

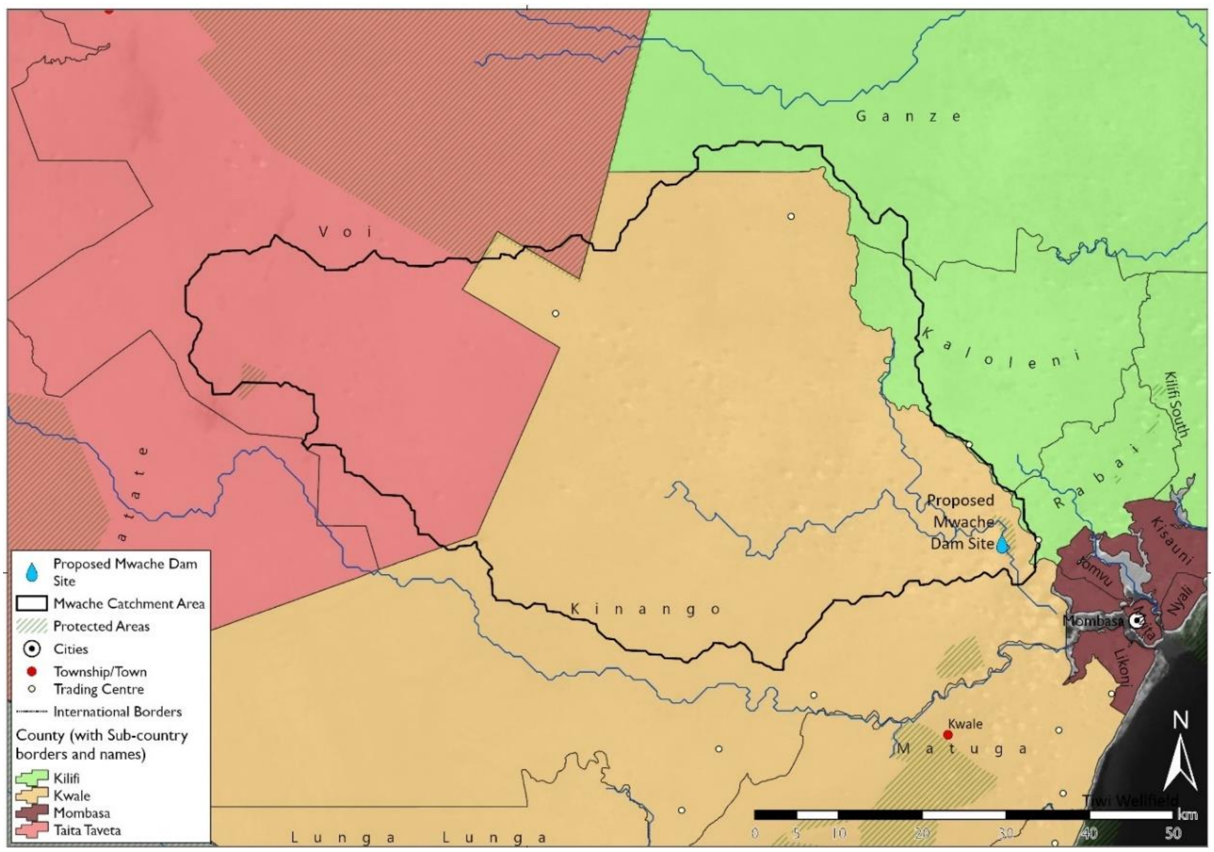


Figure 5-2. Map of counties and sub-counties in the Mwache Dam catchment and surrounding areas

TOPOGRAPHY, AND DRAINAGE

The terrain is mostly flat and slopes gradually downward towards the coast. Drainage is generally west to east. The upper western reaches of the catchment are hilly, rising to about 800-1000 m (Figure 5-3). The rest of the western portion of the catchment is relatively flat with a poorly-defined drainage network. The eastern half of the catchment is largely below 400 m. Terrain becomes more undulating here, characterized by a series of gently sloping river valleys, but no major relief features. Elevation drops to 20 m at the proposed dam site (MEWNR, 2014). The Mwache River eventually discharges into the Indian Ocean through the port areas of Mombasa, located downstream of the proposed dam site. The catchment area comprises 21 sub-catchments.

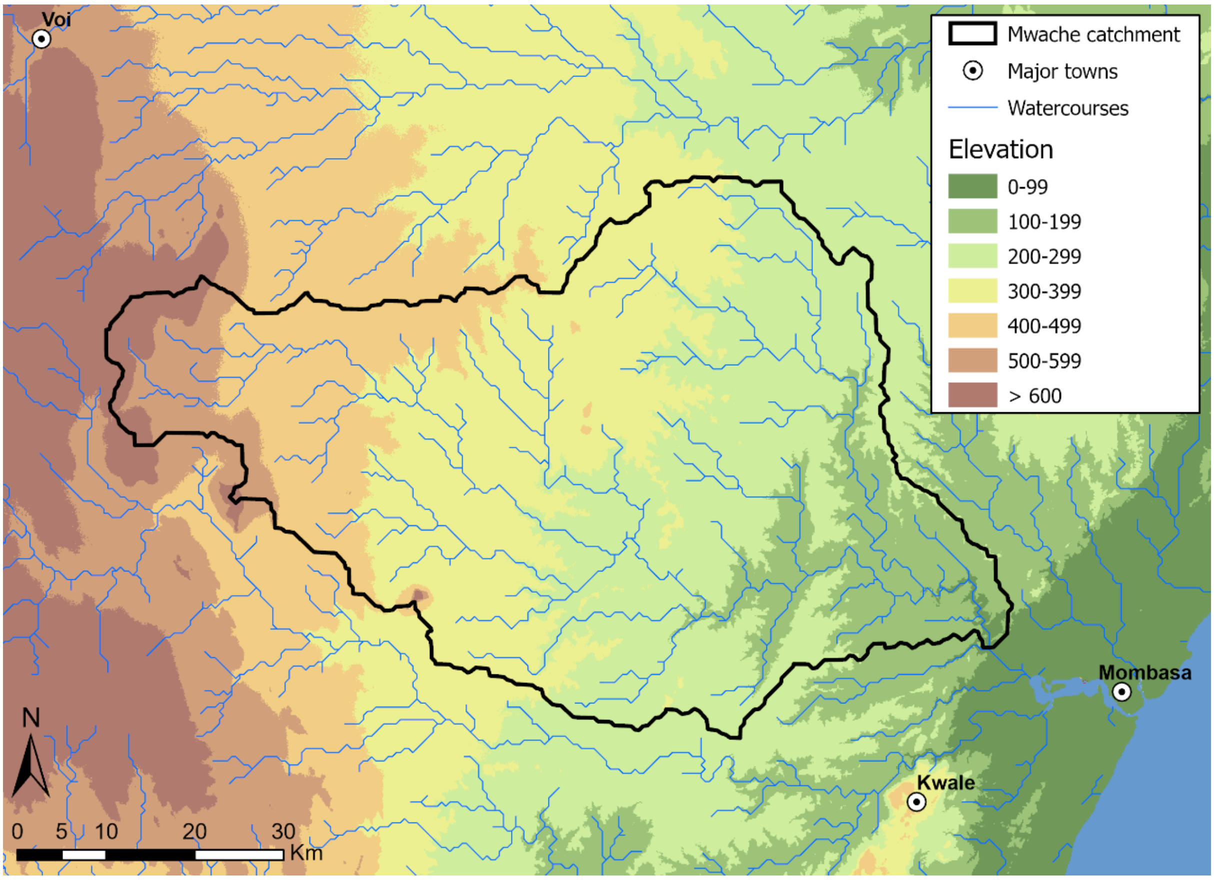


Figure 5-3. Map of elevation and watercourses in the Mwache Dam catchment.

CLIMATE

Most of the catchment is relatively dry and rainfall tends to be highly unreliable (Ochieng *et al.*, 2013). Average annual rainfall increases towards the coast, ranging from 650-800 mm in the west to 900-1100 mm in the east (Figure 5-4). Isolated areas of higher rainfall occur in the hilly areas along the western borders of the catchment. The region experiences a bimodal rainfall pattern, with a short rainy season from October to December and a longer rainy season between April and June, with most of the annual rainfall falling in these months (Ochieng *et al.*, 2013). However, rainfall in the region tends to be highly variable on an inter- and intra-annual basis. Between the two rainy seasons, there is a hot dry season from January to March and a cooler dry season between June and August. Flows in the catchment are highly seasonal with rivers drying up during the dry season, except for pools in the lower reaches of the Mwache River (RTI International, 2017). Mean annual temperatures are relatively high across the catchment, ranging from 22°C in higher-lying hilly areas (800-1000 m altitude) in the west, to 26°C at the bottom of the catchment (> 100 m altitude).

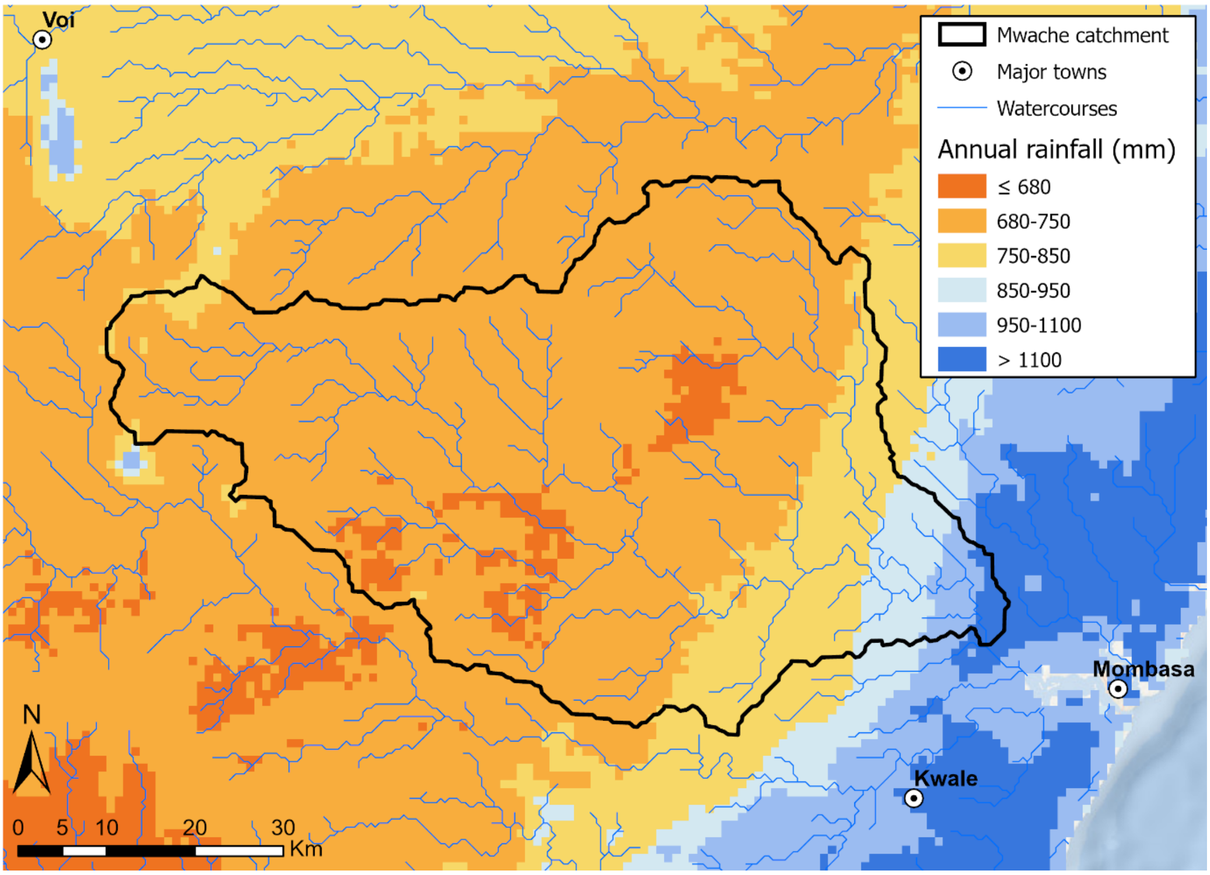


Figure 5-4. Average annual rainfall for the Mwache Dam catchment area. Data source: WorldClim.

NATURAL VEGETATION, LAND USE, LAND COVER AND SOILS

The dominant natural vegetation type in the catchment is *Acacia-Commiphora* deciduous bushland, (van Breugel *et al.*, 2015). *Acacia-Commiphora* bushlands (earlier maps call this "dry bushland and thicket") extends over large areas of the semi-arid regions of eastern Kenya (Figure 5-5) but is one of the most threatened ecosystems in East Africa (Abera *et al.*, 2020). In a natural state, it is characterized by bushes or bushy trees 3-5 m tall, with scattered emergent trees up to 9 m tall (Figure 5-6). In the far east of the catchment where rainfall is higher, *Acacia-Commiphora* bushland transitions to the coastal mosaic vegetation grouping, which includes a range of forest types (van Breugel *et al.*, 2015). However, there is generally no clear vegetation transition on the ground today, which likely reflects habitat transformation. In hilly areas along the western boundaries of the catchment, *Acacia-Commiphora* bushland transitions to Afromontane forest, due to locally elevated rainfall.

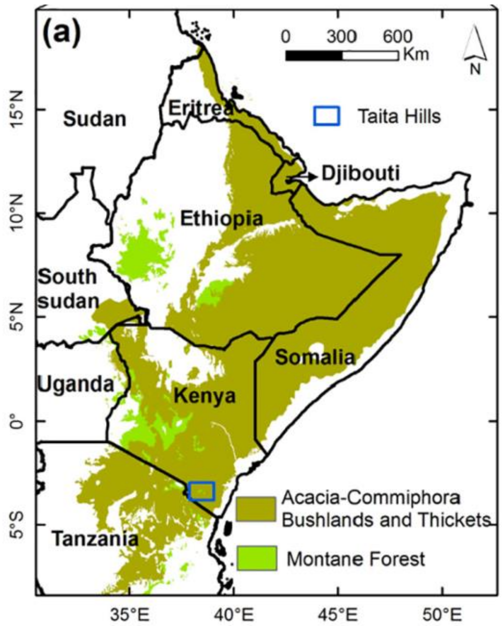


Figure 5-5. Spatial extent of Acacia-Commiphora bushlands in East Africa. Source: Abera et al., (2020), based on Dinerstein et al. (2017) and White (1983)

Figure 5-6. Example of vegetation in a conservancy south of McKinnon Road. Photo: JK Turpie.

The Mwache Dam catchment area has undergone significant anthropogenic land cover change. Land cover data give the best picture of the overall state of current land cover compared to its original coverage of dense bushland and forest. Following a comparison of available land cover products, we selected the European Space Agency - Copernicus Climate Change Initiative (ESA-CCI) 20 m land cover map of Africa (ESA, 2017) as the most accurate dataset for the Mwache Dam catchment. However, the land cover data was supplemented by information on vegetation productivity, measured by the normalized difference vegetation index (NDVI), to provide a guide to vegetation condition. Relatively high resolution (250 m) MODIS satellite data on global NDVI is available from 2001 on a bi-weekly basis. Data on NDVI trajectories derived from MODIS and normalised for changes in rainfall are available through the Trends.Earth platform (Conservation International, 2018). This was used to identify areas in the catchment which have experienced a statistically significant decline in NDVI since 2001(Figure 5-7). Such a decline in NDVI might reflect a total removal of natural vegetation, or a thinning out of vegetation cover due to overgrazing, fuelwood harvesting or other activities. All areas exhibiting a significant decline in NDVI were considered to be degraded. A raster layer of these degraded areas was then combined with the 20 m land cover (ESA, 2017) to integrate information on degradation into the land cover dataset. For example, shrubland areas in the baseline land cover, which were found to be degraded in the NDVI trajectory analysis, were reclassified as degraded shrubland in our integrated land cover product shown in Figure 5-8.

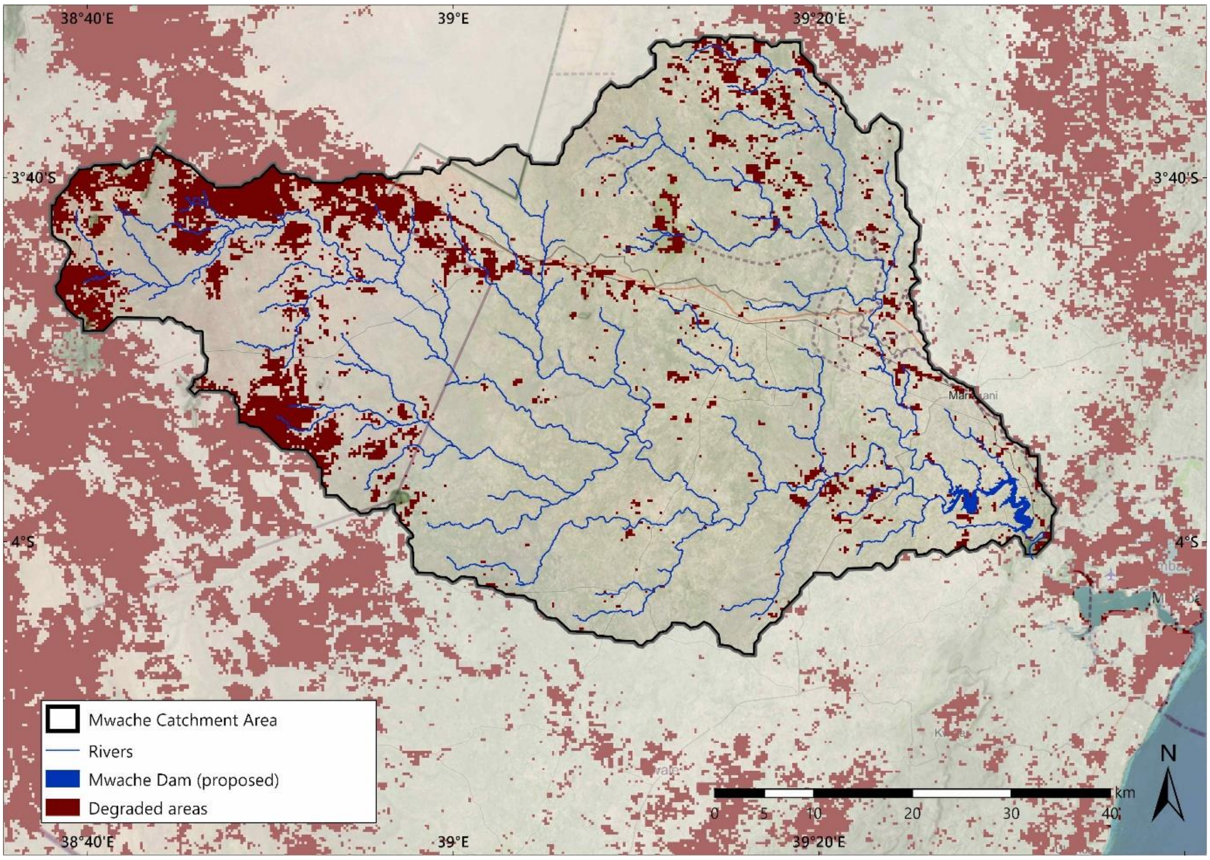


Figure 5-7. Degradation in the Mwache Dam catchment between 2001 and 2018, as measured by a statistically significant decline in NDVI. Data source: Trends.Earth

As indicated by the land cover data, natural vegetation has been opened up or cleared by agriculture, pastoralism and wood harvesting across much of the catchment, particularly in the central and eastern parts (Figure 5-8). Shrubland (= bushland) dominates the catchment (59%) followed by grassland (30%) and cultivation (9.6%). However, most of the areas classified as grassland are not natural but are instead the result of human activities, as was confirmed through field visits to the catchment. These areas thus largely represent currently cultivated, fallow or abandoned agricultural areas, or areas denuded by fuelwood collection. Only 0.8% of the catchment was classed as forest, and 0.1% was classed as urban.

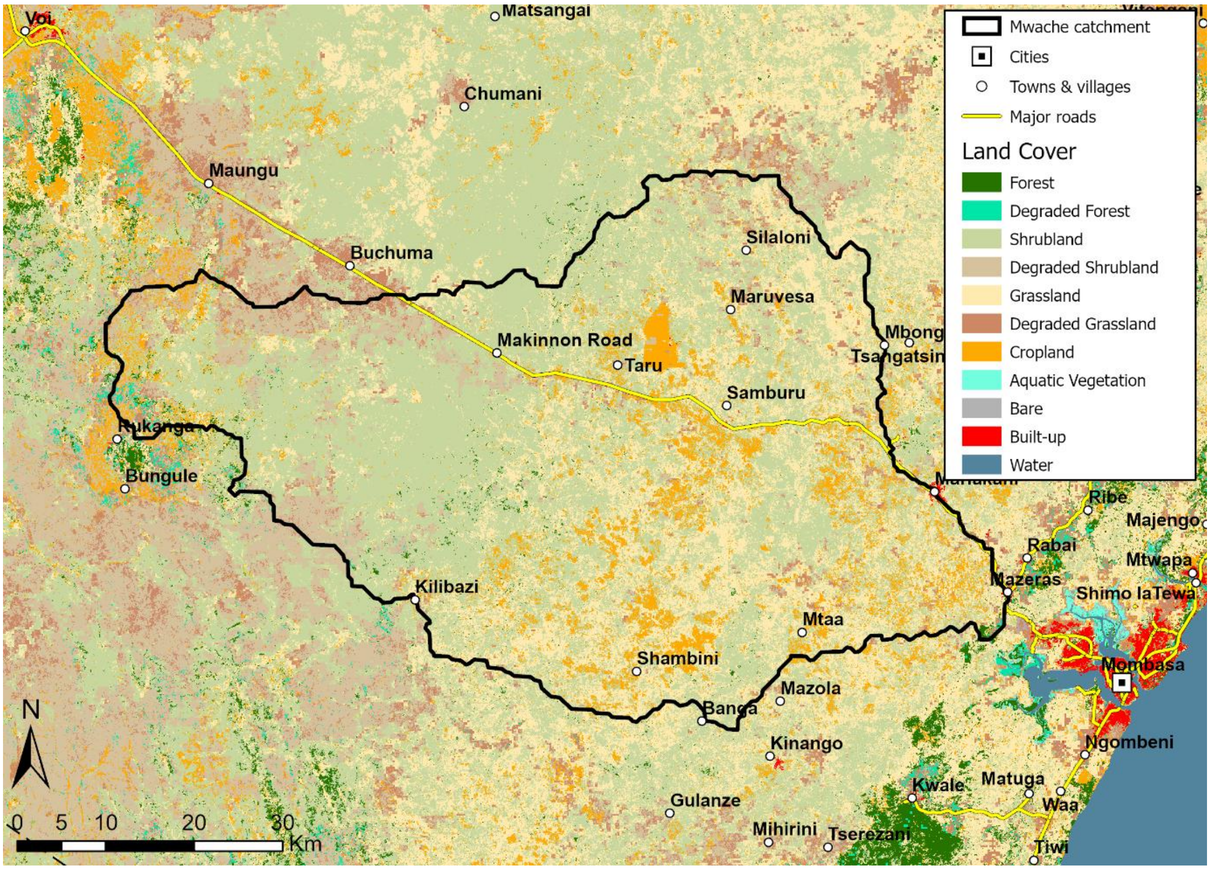


Figure 5-8. Land cover map of the Mwache Dam catchment and surrounding areas. Data source: ESA, (2017) and Conservation International, (2018).

The natural *Acacia-Commiphora* bushland land cover is generally more intact in the western part of the catchment. This area largely consists of group ranches used for livestock grazing and, more recently, conservation, allowing vegetation to remain in a relatively natural state However, large areas of shrubland in this part of the catchment exhibited a decline in NDVI and were thus classed as degraded (Figure 5-8). These areas appear to have been subject to fuelwood harvesting and/or overgrazing. In the extreme west, cropping is prevalent around the higher-rainfall hilly areas (Figure 5-9 and Figure 5-10).

Figure 5-9. View of the Rukanga Mountain from the north. Photo: JK Turpie.

Figure 5-10. Farming at the base of the western hills of the Mwache Dam catchment. Photo: JK Turpie.

More substantial transformation of natural habitats has occurred in the central and eastern parts of the catchment, where cultivation and "grassland" are the dominant land cover classes (Figure 5-8). As already mentioned, a tour of the study area showed that many of the areas classified as "grassland" here are in fact areas denuded of vegetation, mostly representing abandoned or fallow fields (Figure 5-11). Cultivated areas were dominated by maize, although yields were poor at the time of the site visit due to very low rainfall in the preceding season (Figure 5-12).

Figure 5-11. Typical scene in middle Mwache Dam catchment. Photo: JK Turpie.

Figure 5-12. Maize is the most common crop in the middle Mwache Dam catchment. Photo: JK Turpie.

Forest cover was historically much more extensive in the wetter, lower eastern reaches of the catchment (RTI International, 2017). However, very little coastal mosaic forest remains in this part of the catchment due to extensive transformation. Mwache Forest, along the lower reaches of the Mwache River (Figure 5-13), is the only notable area of forest remaining in the area. Nevertheless, satellite data show that deforestation is taking place in the Forest Reserve.

Figure 5-13. Contrast between the cleared area in the foreground and the Mwache Forest Reserve in the background. This is just below the dam site. Photo: JK Turpie.

Soil type has an important bearing on hydrological and erosion processes. Generally, semi-arid areas of Kenya comprise sandy soils prone to crusting and compaction, resulting in low water use efficiency (Biamah, Gichuki & Kaumbutho, 1993). There are ten soil types in the Mwache Dam catchment. The upper catchment is mostly comprised of Ferralsols. These are deep, strongly weathered red or yellow soils that are physically stable and have relatively low erodibility but also low water retention and thus poor for cropping (Fischer *et al.*, 2012). The middle catchment is made up primarily of Luvisols. These are generally fertile soils, characterised by low erosion but limited water storage capacity (Jones *et al.*, 2013). Higher water retention makes this soil group more suitable for planting crops. The lower catchment is the most heterogenous and is made up mostly of Leptosols and Cambisols (Fischer *et al.*, 2012; "SoilGrids," 2021). Leptosols are very shallow (sitting on shallow base rock and previously eroded), with high gravel content and are typical of mountainous regions. Cambisols are loamy to clayey and are the most suitable for agriculture of the main soil types in the catchment with relatively low erosion compared to other soils in the region. The soil erosion and degradation risk ranges from 'slight' in the upper catchment to 'severe' in the lower catchment (Mulinge *et al.* 2016) which is likely in large part to the steeper topography of the catchment lower down.

POPULATION AND SOCIO-ECONOMIC STATUS

The population of the catchment is roughly 202 500 (WorldPop, 2020), with most people living in rural areas, as is reflected by the small area of urban land cover. The western parts of the catchment are generally sparsely populated, with higher population densities in the lower eastern parts of the catchment (Figure 5-14). Most urban centres are located along the very busy Nairobi-Mombasa road, where there are a series of trading centres and small towns, and ribbon development along much of the highway. Settlement becomes increasingly dense along the portion of the highway between Mariakani and Mombasa, where land cover can be increasingly described as peri-urban.

The dominant ethnic group over much of the catchment is the Duruma, particularly in the eastern half (ESC, 2018a). Other ethnic groups include the Taita (particularly in the west), Kamba and Ganze. The urban centers along the Nairobi-Mombasa highway tend to have a mixture of ethnic groups (ESC, 2018a). While Duruma is the dominant language, most inhabitants also speak Swahili (ESC, 2018a).

Poverty levels are relatively high, with 43% of the population living below the poverty line (ESC, 2018a). In the poorest parts of the catchment, poverty levels rise as high as 70% (RTI International, 2017). Low and irregular incomes have been identified as a significant driver of environmentally damaging (and often illegal) activities such as logging, artisanal mining and sand harvesting. In keeping with the high levels of poverty, levels of education are also low. In their household survey, ESC (2018) found that only 30% of household heads had completed primary school education, 30% had not completed primary school and 20% had not received any formal education at all. Just 9% had completed secondary education. Nevertheless, the literacy rate among household heads was found to be comparable to the national average at 81% (ESC, 2018a). However, a much lower literacy rate of 49% has also been reported for the catchment (RTI International, 2017).

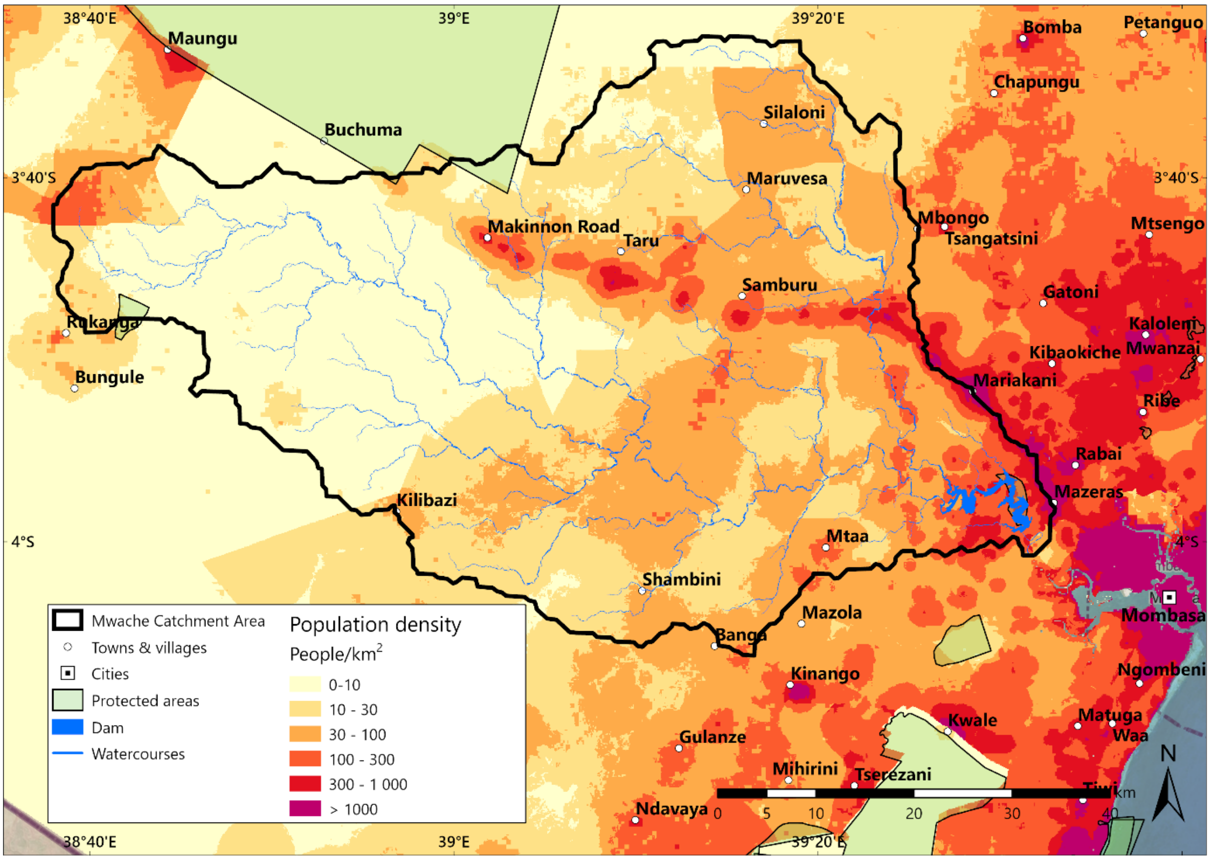


Figure 5-14. Map showing population densities across the Mwache Dam catchment

The use of traditional building materials remains prevalent in the catchment. The census data indicate that walls made from mud and poles are dominant in Kinango Subcounty (67.3%), which encompasses most of the central and eastern parts of the catchment (KNBS, 2019b). Modern building materials appear to be more prevalent in the western part of the catchment, as just over half of houses in Voi Subcounty are constructed with brick or cement (KNBS, 2019b). According to census data, most households across all subcounties which intersect with the catchment use iron sheets for roofing, though a notable portion of houses in Kinango (29.7%), Ganze (19.3%) and Kaloleni (16.4%) use *makuti* (woven coconut palm fronds) or grass (KNBS, 2019b). In contrast (ESC, 2018a) reported that *most* households sampled in the catchment used grass or *makuti*, possibly because they surveyed in relatively remote areas. Our observations aligned with the census data. Where natural materials were used, *makuti* was dominant, and thatching grass was rare. This was unsurprising given the lack of grass.

In keeping with most of rural Kenya, firewood is the dominant source of cooking energy in the catchment, used by 75.5% of households surveyed by (ESC, 2018a), with 14.8% using charcoal. This is broadly consistent with census data, except for Voi Subcounty where firewood was only reported as a cooking source by 36.4% of households, with 29.1% using charcoal and 23.0% using gas (KNBS, 2019b). However, the parts of the Voi Subcounty within the Mwache Dam catchment are very remote and would be expected to be more reliant on firewood (ESC, 2018a).

Survey data suggests most households in the catchment rely on tap water (43.2%) or borehole and well water (21.5%) for drinking, with just 9.9% reliant on surface water (ESC, 2018a). Rainwater harvesting was not widely practiced, carried out by just 4.8% of surveyed households. The prevalence of thatched roofs, which are not suitable for rainwater harvesting, was suggested as a possible reason for this (ESC, 2018a). The census data for Kinango subcounty suggests that 76.0% of households obtain water from ponds or small dams (KNBS, 2019b).

Sanitation is relatively poor in the catchment, with 38.5% of households surveyed lacking sanitation facilities, leading residents to resort to open defecation (ESC, 2018a). In Kinango Subcounty, 53.8% of households practice open defecation (KNBS, 2019b). Even where households have latrines, these are prone to collapse and the majority lack septic tanks (ESC, 2018a). Furthermore, local custom prohibits the use of the same toilets by children and parents, and by householders and their visitors, further necessitating use of the bush (F. Kihara, TNC, pers. comm.). As a result, human waste disposal presents a serious threat to the quality of ground and surface water resources and to human health in the catchment.

LAND TENURE

Since gaining independence in the 1960s, the Kenyan government has attempted to implement land reform programs to move away from communal land ownership and encourage individualized land rights (Narh *et al.*, 2016). However, there has been limited progress in adjudicating and allocating title deeds in the Mwache region (Mbudyza, Ayuya & Mshenga, 2017; RTI International, 2017). Over much of the central and eastern parts of the catchment, land is still held in trust by the county government (ESC, 2018a). Some land has been leased out to communities by the government, while a number of households rent land from private land holders (Mbudyza *et al.*, 2017; RTI International, 2017). Thus, most of the catchment's population still has either temporary or no legal ownership of the land under their management (RTI International, 2017). This appears to contrast with the ESC's (2018) survey findings in which 82% of respondents said they owned the land they cultivated. However, the same study found that only 31% of respondents had title deeds for their land. As most households in the area thus still lack formal land ownership, incentives to engage in long-term investments on their land are lacking (RTI International, 2017).

A somewhat different land tenure situation occurs in the western parts of the catchment falling within Taita-Taveta County (Figure 5-15). Land tenure here is mostly in the form of group ranches which are represented by the Taita Taveta Wildlife Conservation Association (TTWCA). Prior to independence, these ranches were hunting blocks in communal land areas, which were later converted into cattle ranches.

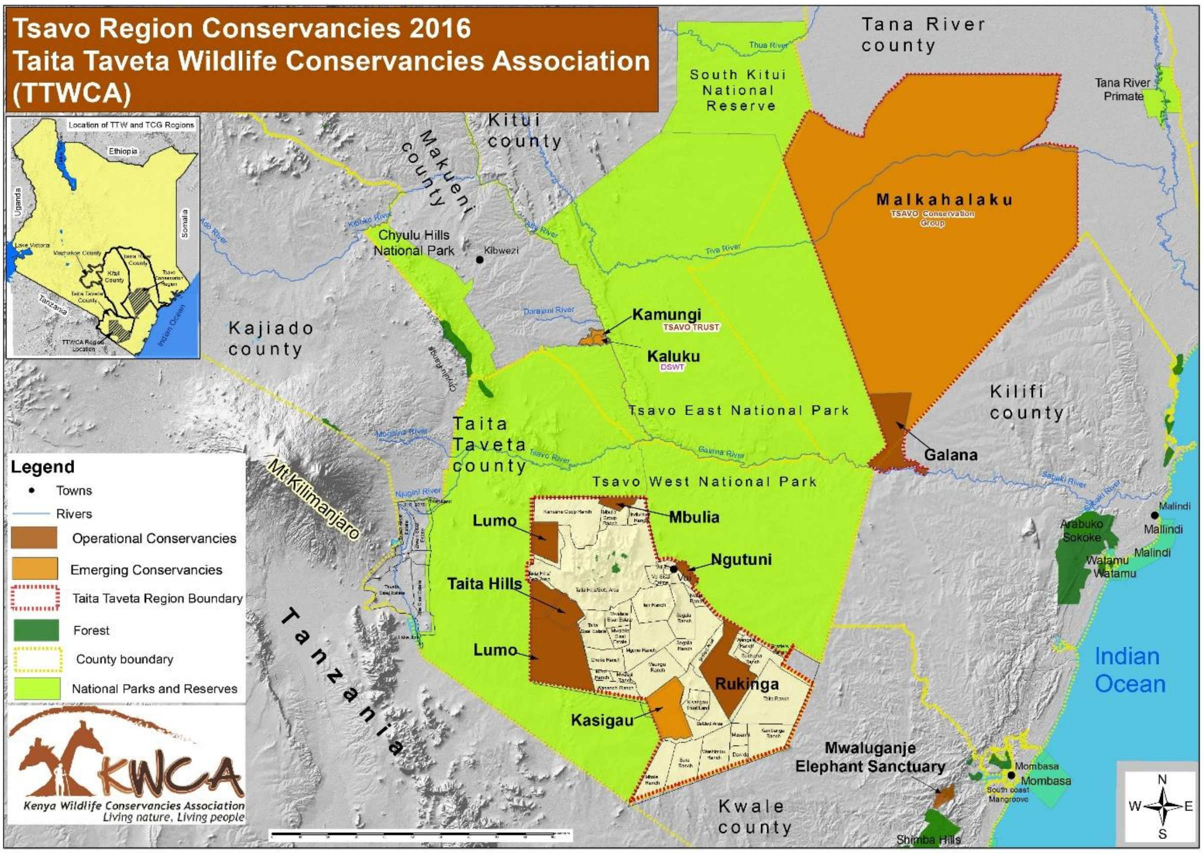


Figure 5-15. The Tsavo region conservancies that are represented by the TTWCA, as at 2016. The far western portion of the Mwache Dam catchment falls within the southern section of Taita-Taveta County bordering onto the Rukinga Conservancy. Source: Kenya Wildlife Conservancies Association (KWCA).

In 2004, the ranches came together to form the Taita Taveta Ranches Association (TTRA) with the shared vision of trying to improve rangeland health and management. Following this, the Kenya Wildlife Service (KWS) engaged with landowners about the potential for developing wildlife conservancies to enable further income generation through tourism activities associated with the Tsavo East and Tsavo West National Parks. This led to ranchers declaring their land as wildlife conservancies. In 2012, the TTWCA was established to support these newly developed conservancies and other ranches to improve rangeland health and the sustainable management and utilization of natural resources across the greater Tsavo ecosystem. Seven ranches have put their land under conservation management to form the Tsavo Conservancy. A large portion of this 100,000 ha area falls within the upper part of the Mwache Dam catchment.

Only a very small portion of the catchment falls within formally protected areas. A small area in the northwest of the catchment falls within Tsavo East National Park. Part of Kasigau Forest Reserve falls inside the upper western part of the catchment, and the Mwache Forest Reserve is located within the lower reaches of the catchment, close to the proposed dam site. However, both of these forest reserves appear to have been heavily encroached by agriculture and settlement.

LIVELIHOOD ACTIVITIES

Farming is a key livelihood activity and income source across much of the catchment (ESC, 2018a). Farming practices vary according to climate and land tenure regimes. In the central and eastern parts of the catchment, most farming households practice a mixture of crop cultivation and livestock rearing (RTI International, 2017; KNBS, 2019b). According to census data, 88.5% of households in Kinango Subcounty farm, with 93.8% of these households cultivating crops and 74.3% rearing livestock (KNBS, 2019b). Crop production is mostly for subsistence purposes, though crop sales do also provide an important source of income for some households (Wekesa *et al.*, 2017). Much less cultivation occurs in the sparsely populated western parts of the catchment, where livestock farming on group ranches is the dominant activity (Rural Focus Ltd, 2020). Conservation has also recently become a key land use in this area with the formation of the Tsavo Conservancy. Due to low agricultural potential, livestock sales are a major source of household income across much of the semi-arid to arid parts of the catchment (Wekesa *et al.*, 2017).

Figure 5-16. Farming maize in the upper catchment area. Photo: JK Turpie.

Throughout the catchment, maize is the dominant crop (Figure 5-16) and is grown by almost all households who engage in crop production (KNBS, 2019b). Other important crops include cowpeas, cassava, beans, green grams and groundnuts (ESC, 2018a). Some farming of cash crops also occurs in the catchment. In the Kinango portion, fruit farming is an important activity, with pawpaw, mangoes, coconuts and oranges being some of the key products (RTI International, 2017). Sisal and cashew nuts are also important cash crops in the drier parts of the catchment, with a large commercial sisal estate located near Taru.

Among households which keep ruminant livestock, goats are the most abundant type, followed by cattle and sheep. In Kinango Subcounty, livestock-rearing households have an average of 8.1 goats, 6.0 cattle and 2.3 sheep (KNBS, 2019b). This is likely representative of the situation in the central and eastern parts of the catchment. Goats appear to be more dominant in the western parts of the catchment, with census data suggesting an average of 6.1 goats, 2.8 cattle and just 0.9 sheep in Voi subcounty (KNBS, 2019b). Bee-keeping is not widely practiced in the region, with less than 1% of households in Kinango, Ganze and Kaloeni Subcounties having bee hives and 1.5% of households in Voi Subcounty (KNBS, 2019b). Approximate total livestock numbers in the catchment derived from Gilbert *et al.*, (2018) are around 146 000 cattle, with highest densities along eastern boundary of catchment, followed by the most westerly quarter. The total number of goats is similar, with the highest density again along the eastern boundary of the catchment. The total number of sheep is lower at around 33 000, with densities increasing from west to east.

Highly unreliable rains in the region make agriculture challenging (Ochieng *et al.*, 2013). Most of the catchment is dry with low agricultural potential and the area is prone to periodic food shortages (Wekesa *et al.*, 2017; ESC, 2018a). This has been exacerbated by climate change, which has been blamed for increasingly unpredictable rainfall, longer dry periods and an increase in pests, weeds and disease (Wekesa *et al.*, 2017). Due to poor agricultural productivity, crop farming is in fact said to be declining in importance as a livelihood activity in the region. As a result, there has been an increasing shift to alternative activities, as well as people leaving in search of better farmland or work opportunities in urban centres like Mombasa (Wekesa *et al.*, 2017).

Alternatives in the catchment include sand mining, firewood harvesting and charcoal production (Figure 5-17), all of which are major contributors to environmental degradation and erosion. Poverty, often related to poor agricultural yields, is a key driver of these destructive activities, which are viewed as additional or alternative income sources by local residents (RTI International, 2017; ESC, 2018a). The other key driver is the growing demand for charcoal and building materials from urban markets (RTI International, 2017).

Figure 5-17. Charcoal trader in Mwache Dam catchment. Photo: JK Turpie.

CATCHMENT DEGRADATION AND DRIVERS

The main threats to water security in the Mwache Dam catchment area are those that affect the yield and water quality of the Mwache Dam. These have been primarily identified as a loss of vegetation cover leading to erosion and potential sedimentation of the dam.

LOSS OF VEGETATIVE COVER AND ELEVATED EROSION

Agricultural practices are a significant cause of degradation in Mwache Dam catchment. Large areas of arable land are bare during dry periods, increasing the risk of erosion by wind or rain, and few farmers employ measures to prevent soil loss (RTI International, 2017; ESC, 2018a). Insecure land tenure could be a contributing factor to poor land management practices. For example, soil conservation measures like terraces are time consuming and labor intensive to build. The incentive to invest in such measures is likely to be reduced where long-term ownership of land is not assured or where it is possible to simply move to a new patch. Farming in riparian zones is also widespread and particularly problematic for increasing sediment export to watercourses (Figure 5-18). Riparian zones are particularly attractive for farming in the area, due to generally poor soils and low, unreliable rainfall. In this study, the farming areas were observed after the long rains had failed, and widespread crop failure was evident, leaving fields bare for longer than usual. This suggests that with climate change, soil erosion from failed croplands could become an increasingly serious issue.

Figure 5-18. Erosion associated with agriculture near Mariakani. Photo: JK Turpie.

Overgrazing is also an issue which has also contributed to the loss of vegetation cover in parts of the catchment (RTI International, 2017). Large numbers of livestock were observed in the catchment, including in areas that were highly denuded. This prevents the recovery of vegetative cover on unused cropland as well as reducing grass cover away from fields. Furthermore, herders bring their livestock to rivers to drink, damaging bank vegetation and generating major erosion (Figure 5-19).

Loss of woody cover due to fuelwood harvesting is another major issue in the catchment. Charcoal production is increasingly seen as a livelihood option in the face of poor agricultural yields, drought and worsening poverty, while growing urban centres in and around the catchment create a readily available and expanding market (RTI International, 2017). The availability of road networks which provide easy connectivity between many parts of the watershed and nearby urban centers further increases the attractiveness of the area for charcoal harvesting (RTI International, 2017). Field visits to the southern and eastern parts of the catchment confirmed the impact of fuelwood harvesting, as very few mature trees were left standing in these areas. The demand for building materials exerts further pressure on remaining wood resources in the area.

Figure 5-19. Examples of riparian condition. Photo: JK Turpie.

Global Forest Watch has been monitoring changes in forest cover at a global scale since 2001 using satellite data, based on the methods initially described by Hansen *et al.* (2013). As the methods are more suited to detecting changes in taller forest vegetation than in bushland, the change in woody biomass has to be fairly significant in order to be detected. Nevertheless, the Global Forest Watch data for the study area indicate notable deforestation in parts of the catchment, particularly in the middle reaches (Figure 5-20). Little deforestation is apparent in the sparsely populated western parts of the catchment where natural vegetation remains largely intact, except for the hilly areas along the western boundaries of the catchment where some clearance of forest for agriculture and settlement has occurred.

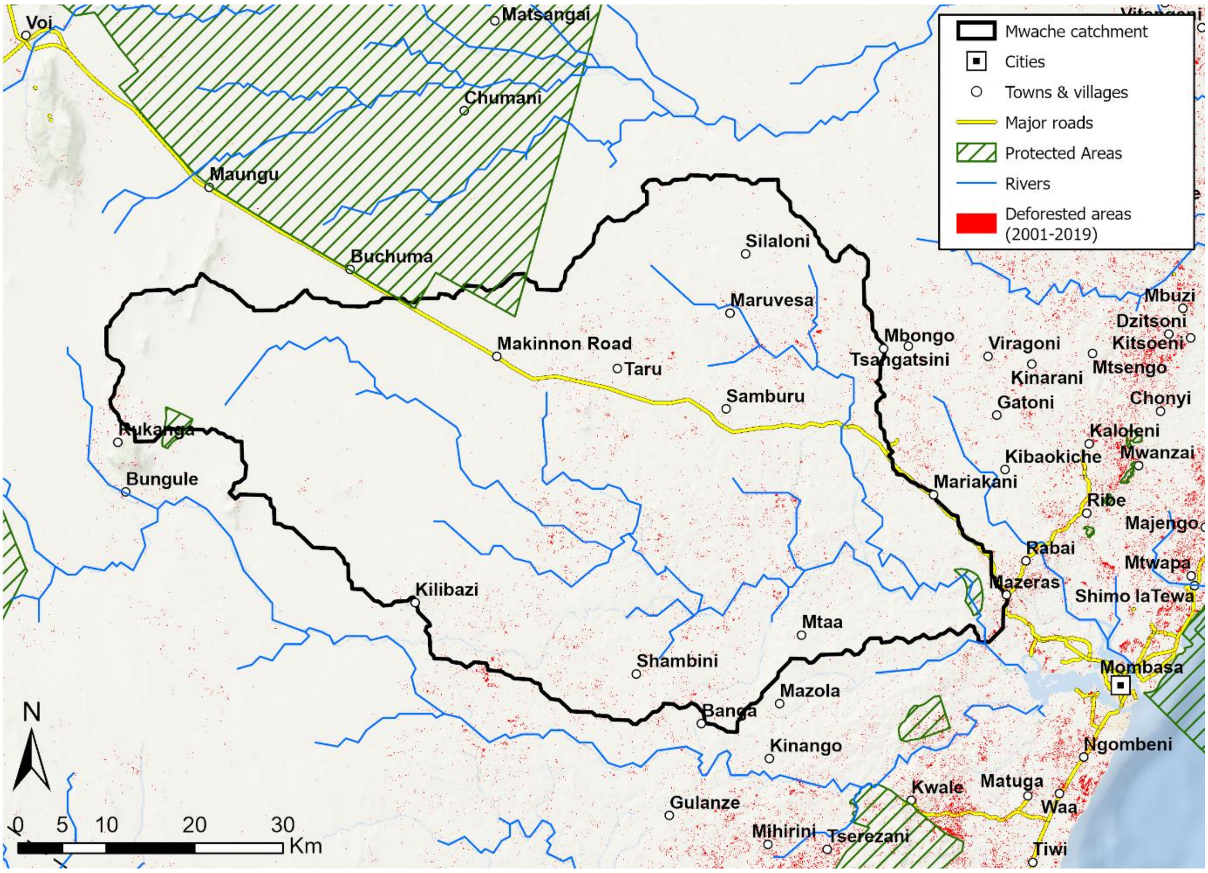


Figure 5-20. Map showing areas deforested between 2001 and 2019. Data from Global Forest Watch. Methods described in Hansen et al. (2013)

According to these data, some 2640 ha of land has been markedly deforested (or de-bushed) between 2001 and 2020, which is an average of 132 ha per year. Note that much of the deforestation in the catchment likely took place before 2001, predating the Global Forest Watch data. Analysis of deforestation over time shows no obvious trend, with high variation in deforestation levels evident from year to year (Figure 5-21 and Figure 5-22). Notably, very limited deforestation was detected between 2015 and 2020. This could be related to the fact that this was a wetter-than-usual period, and so the need to produce charcoal for income may have been reduced. Nevertheless, it is widely reported that deforestation for charcoal production is increasing.

Overall, it has been suggested that local communities have a limited understanding of the relationship between water quality and land management practices, resulting in activities like riparian farming and deforestation which carry a high risk of siltation (RTI International, 2017). But even if they did understand these impacts, there is no incentive to change these practices. The combined effects of degraded agricultural lands, overgrazing, riverbank degradation and deforestation are the loss of vegetative cover in the landscape, which exposes soil to erosion. As already mentioned, natural vegetation over much of the catchment has been opened up, with 9.6% of the catchment classed as cultivation according to the land cover data we used. However, we also noted that most of the areas classed as grassland (30% of the catchment) reflect fallow fields or denudation of natural vegetation by overgrazing or fuelwood harvesting.

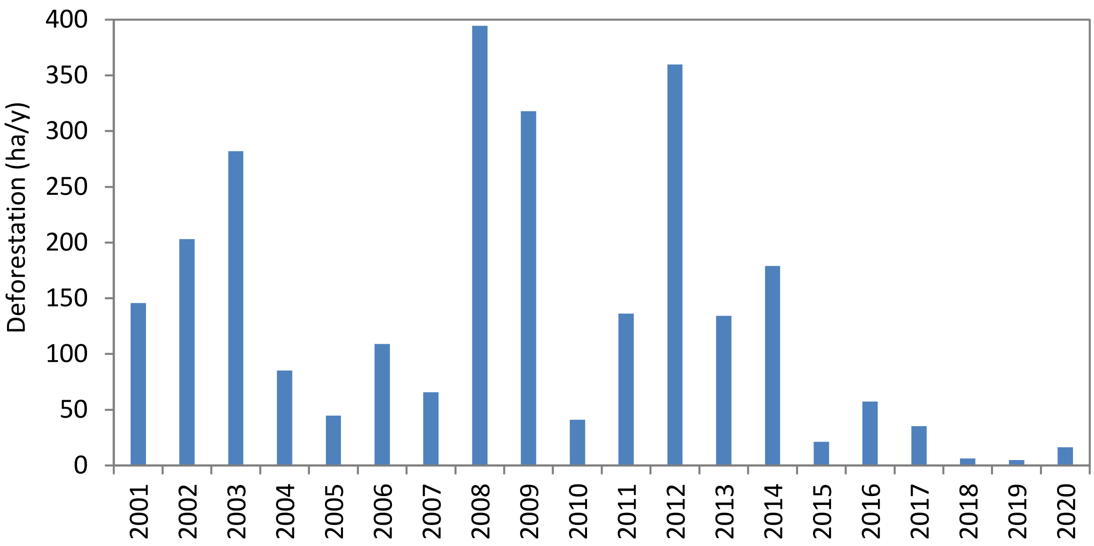


Figure 5-21. Deforestation per year across the Mwache Dam catchment according to Global Forest Watch data (methods described by (Hansen et al., 2013).

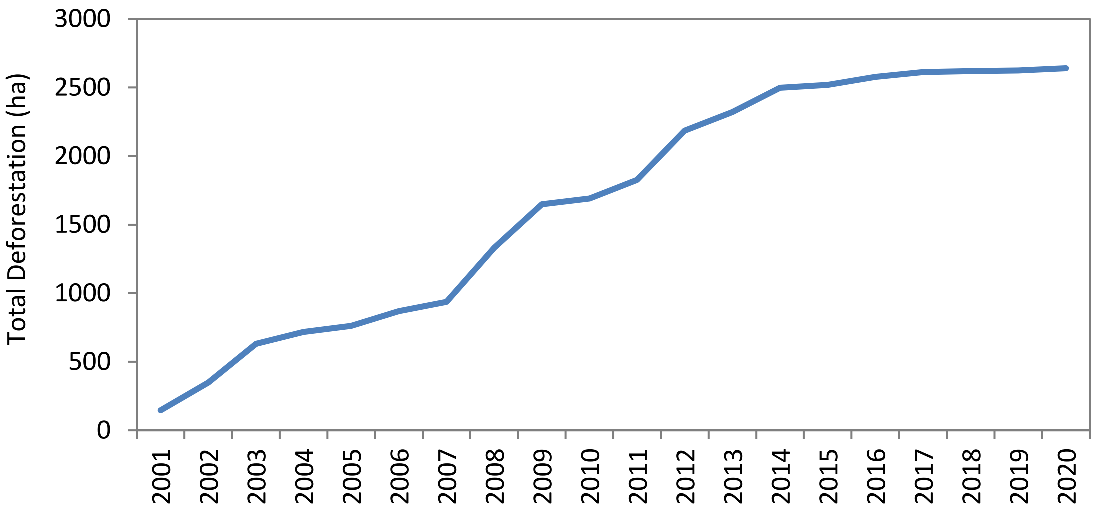


Figure 5-22. Cumulative deforestation across the Mwache Dam catchment from 2001-2020 according to Global Forest Watch data (methods described by Hansen et al., 2013).

WATER QUALITY ISSUES

Water quality data is limited for the catchment. However, the little sampling that has been undertaken suggests sedimentation is the major water quality issue. In samples taken as part of the physiographic study (RTI International, 2017), most water quality parameters were within Kenya's regulatory limits. However, very high levels of total suspended solids (TSS) in these samples were an exception. Total suspended solids ranged from 428-1050 mg/l in samples taken from the Ngoni River and from 912-1370 mg/l in Mwache River samples. These are all well above the 30 mg/l limit for TSS in the Kenyan water quality regulations. Aluminum concentrations were also above the regulatory limit in most samples. However, it was suggested that this reflected the high TSS levels, due to the aluminum content in the eroded soils (RTI International, 2017). No other water quality issues emerged in this study, save for one Mwache River sample which exceeded limits for biological oxygen demand, chemical oxygen demand and oil and grease, which could be indicative if industrial effluent pollution. Another exception was a different Mwache River sample which exceeded limits for faecal coliform bacteria, suggesting pollution from human and/or animal wastes (RTI International, 2017). These single sample results suggest isolated instances of industrial effluent and biological waste pollution in parts of the catchment. All other water quality parameters, including pH, total dissolved solids, electrical conductivity, nutrients, chloride, fluoride, sulphur, E. coli and metals, were well within regulatory limits (RTI International, 2017). Similar results were reported by KWSCRP (2016), who found that water quality parameters were within limits, except for elevated turbidity and suspended solids, again suggesting sediment export is the major water quality issue in the catchment.

EVALUATION OF POTENTIAL INTERVENTIONS

APPROACH

Types of interventions considered

The Mwache Dam Physiographic Study suggested a number of soil conservation practices to address land degradation. These included conservation agriculture and agroforestry (combined), terracing and household ponds in cropland areas, water pans or dams and grass strips to reduce sediment export from micro-catchments in "grassland" areas[17], forestry management, and farmer-managed natural regeneration in shrublands (see Table 4-2). Details were not provided on the rationale for these, nor on where they should be implemented. The Options Study revisited the potential choice of interventions based on a review of the international literature on a broad range of nature-based interventions, and also investigated their potential suitability from a social point of view. It provided a long list of suggested interventions[18], but did not provide guidance as to their location or extent. From the review of these two studies, it was recognized that the classification and clear description of interventions, their intended purpose and likely effectiveness in different contexts is very important. In addition, it would be beneficial for the Water Fund to narrow down the options to just a few effective interventions and have a clear and simple plan. It is also important to remain focused on the water security objective.

Catchment management interventions to address water security focus on maintaining land cover and minimising erosion and pollution, as well as water conservation. These can be addressed with nature-based or engineering interventions. For some issues, such as poor sanitation, engineering solutions can be key. For others, nature-based solutions can be more efficient. In many cases, engineering and nature-based solutions are highly complementary (Turpie *et al.*, 2017). This study focuses on nature-based interventions to restore and maintain

[17] Note that there are no natural grassland areas in the catchment and very few areas that are secondary grassland. We believe this is due to incorrect classification of satellite data.

[18] Interventions suggested in the Options Study included: improvement in water usage efficiency; Protection of vulnerable lands by planting trees of economic value; Encourage the creation/development of community and private forests; Planting leguminous crops like green grams, cow peas, beans; Stonewalling/bunding; Rehabilitation of degraded lands- through FMNR, tree planting, controlled grazing; Terracing steep-sloped land; Wetland terracing; Rehabilitation and maintenance of riparian zones, riparian pegging, restoration, grass buffer strips, grass planting in water ways; Contour ploughing; Hedgerows; Agroforestry; Orchard plantation; Improved seeds/crops; Manure shed construction; Improved sanitation; and Capacity building.

land cover and minimise erosion. Drawing on previous studies in the region as well as the international literature, we review the different types of nature-based solutions used in semi-arid landscapes to address these issues, and the biophysical and socio-economic factors affecting their potential suitability and success.

Nature-based catchment interventions can be broadly divided into rehabilitation or conservation measures, with the latter being through sustainable land management practices or protection. For this study, we have broadly categorised these as follows (Figure 5-23):

- Active restoration or rehabilitation;
- Soil conservation on farmland;
- Sustainable natural resources (e.g. woodfuel) harvesting;
- Sustainable rangeland management; and
- Protected areas/conservation areas.

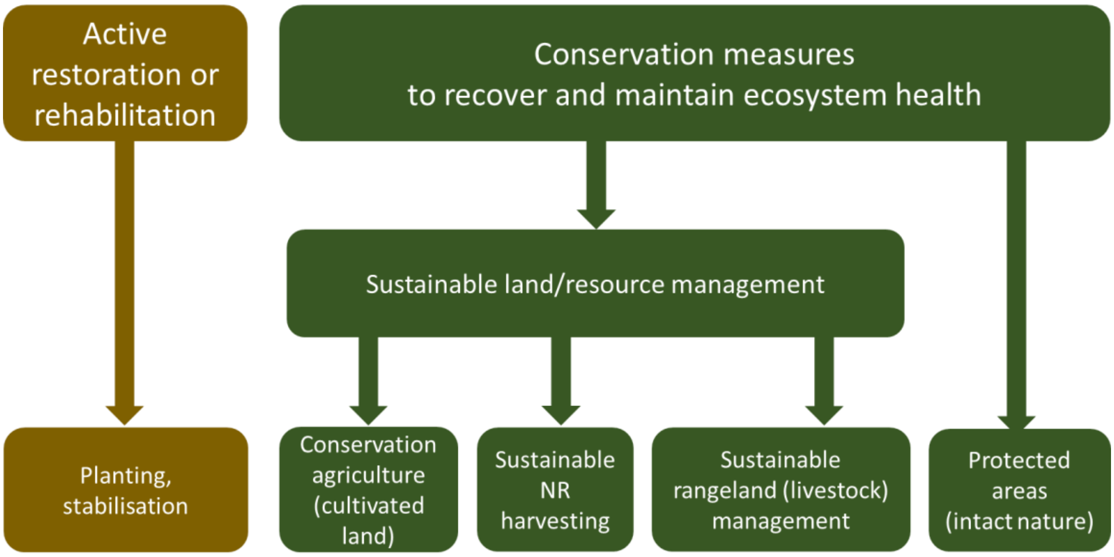


Figure 5-23. Typology of catchment interventions considered in this study.

Note that the middle three types are forms of sustainable land management (SLM). These measures pertain to the management of land areas used being used for production, as opposed to protected areas, which are defined here as areas protected from any consumptive use. Active restoration, such as grass or tree planting, can occur on productive areas or protected areas, and may be followed by conservation measures. In general, the prevention of degradation through sustainable land management or strict protection is less costly than rehabilitation, and so future pressures also should be taken into account in identifying appropriate interventions. Protection is appropriate for areas of critical importance for ecosystem services, with riparian areas, steep mountain areas and high rainfall areas ("water towers") being good examples of the latter in the context of water security.

The objectives of the interventions in the study area are aligned to Kenya's national obligations for achieving land degradation neutrality (LDN), i.e. no net degradation relative to 2015, by 2030. It is envisaged that these targets will be met primarily through SLM, but will also require some degree of restoration (Turpie et al. 2021). Avoiding degradation is regarded as the primary mechanism for limiting degradation and achieving land degradation neutrality (LDN, Cowie *et al.*, 2018). Sediment loads and quick flow can be reduced by up to 40% if SLM interventions are implemented (Tenge, Sterk & Okoba, 2011). This can have major positive implications for water supply.

A 'catchment approach' to SLM has been employed in several parts of Kenya (Liniger *et al.*, 2011). This involves the implementation of SLM measures at catchment scale, although implemented within administrative or culturally defined areas for easier logistics and administration. Committees from each region include local farmers and community leaders, as well as members from NGOs and relevant government entities. Local farmers carry out the majority of interventions proposed, with financial assistance from the government, donors or NGOs (Pretty, Thompson & Kiara, 1995; Liniger *et al.*, 2011).

Therefore, based on the likely effectiveness of a range of potential measures, the biophysical characteristics of the catchment and land use activities, and the likely acceptability of different options under the socio-economic and institutional context, the following combination of environmental management measures is proposed for the MWF:

i. Active rehabilitation, which includes planting appropriate trees and grass in badly degraded riparian and roadside areas and restoring tree cover in deforested areas;

ii. Soil erosion control (SEC) interventions on farmland, including cover crops, reduced and no tillage approaches, agroforestry, and terracing, with different combinations of interventions proposed depending on slope;

iii. Sustainable natural resource management, which includes sustainable rangeland management, sustainable use of fuelwood, and the managed recovery of degraded areas; and

iv. Conservation of important natural areas, which includes protection of all riparian zones and the establishment of community wildlife conservation areas (i.e., potential expansion of conservancy areas) in larger blocks of remaining natural vegetation that are not currently protected.

Identifying potential for implementation in the catchment area and estimating costs

The potential extent of selected interventions was identified using various spatial datasets in GIS, based on factors such as land cover and condition, protection status, main crop type and slope. The various spatial datasets used in the mapping of potential intervention locations are summarized in Table 5-1. Rivers were delineated using the InVEST stream delineation output to ensure consistency in subsequent modelling. All GIS layers were pre-processed by either converting them to a raster layer (from vector if necessary), resampling them to the same projection (WGS 84 / UTM zone 37S) and snapping them to the original land cover layer. Combination of the various spatial datasets resulted in an initial layer with 218 land cover, condition, tenure status and slope combinations. Redundant classes were combine and reclassified to produce a final layer with 70 classes. This layer had a nominal spatial resolution of 20.531 m.[19]

[19] Difference from 20 owing to the projection used and location on the earth's surface.

Table 5-1. Data sources used to create 'Master' augmented land cover layer for mapping proposed interventions.

Dataset	Resolution	Source	Method to standardise
Land Cover	20.53 m	ESA (2017), augmented with NDVI trend data derived from Trends.Earth	N/A
River buffers riparian zone	N/A	InVEST hydrological services stream delineation[20]	Rivers converted to shapefile. Buffered by 30 m on either side. Buffer area converted to raster. Snapped to land cover. NA values converted to 0.
Water extent (wetlands)	30 m	Pekel *et al.* (2016)	Resampled to 20.53 m using bilinear rule. Snapped to land cover.
Deforestation/Forest loss	30 m	Hansen *et al.* (2013)	Resampled using majority rule. Snapped to land cover. NA values converted to 0.
Main crop type	30.10 m	RCMRD (2017)	Resampled using majority rule. Snapped to land cover.
Protected areas	N/A	UNEP-WCMC & IUCN (2021)	Forest reserves excluded as locations were incorrect. Converted to raster. Tsavo Conservancy digitised and 'burnt' into raster

The 70-class layer of different land cover, condition, tenure status and slope classes was then used to map potential areas for the proposed interventions. For example, cultivated areas with slopes exceeding 9% were considered potential sites for terracing. Further description of the criteria used to identify potential extents of each proposed intervention is provided later in the chapter.

Consideration of social suitability

The decisions as to the choice and extent of implementation of different catchment conservation measures will be influenced by the cost-effectiveness, from an investors point of view, and their likely success based on their level of local support. Land users will be more willing to accept interventions which do not require too much input and from which they can benefit without too much delay. Interventions that require landowners to give up short term benefits will therefore require financial input in order to be supported, such as compensation or payments for ecosystem services. These factors are discussed in the sections below.

While subsistence farmers may be willing to implement sustainable land management interventions, resource gaps such as insufficient labour, lack of tools and inputs and insufficient knowledge and awareness are common barriers to uptake (Dallimer *et al.*, 2018). Hence, assistance of local communities in the establishment of catchment management interventions may be needed, particularly where costs exceed the means of local land users and/or where quick benefits are not guaranteed. Where external support is lacking, interventions with low material requirements and input costs will likely be most appealing to local farmers (Dallimer *et al.*, 2018). In some cases, it will be hard to gain acceptance for certain important interventions. For example, farmers cultivating in riparian buffers will likely be resistant to efforts to conserve and rehabilitate these areas, even though this intervention is crucial to reducing sedimentation of watercourses. The description of each intervention later in this

[20] See SDR: Sediment Delivery Ratio

chapter will be accompanied by a discussion of their social suitability and acceptability as well as possible models of implementation.

ACTIVE RESTORATION OR REHABILITATION

Degraded areas that pose a high risk to water security may require active restoration or rehabilitation. Two frequently applied nature-based solutions are the planting of grass cover in highly eroded areas, and tree planting in riparian areas. This is particularly relevant given that the 2020s decade has been declared the Decade of Ecosystem on Ecosystem Restoration by the United Nations (UN).

Types of interventions and their potential efficacy

Active rehabilitation (non-riparian areas)

Tree planting has frequently been advocated for catchment restoration, including in the Mwache Dam catchment (RTI International, 2017; ESC, 2018a). Enrichment planting and assisted natural regeneration (ANR) could be used to increase tree cover in forest and shrubland areas which have been subject to deforestation. According to Chomba *et al.*, (2020), enrichment planting refers to the deliberate planting of trees in areas where natural regeneration is also occurring, while ANR involves deliberate protection and preservation of naturally regenerating vegetation. In many cases, a combination of these approaches might be needed in the study area. For example, enrichment planting might be needed to kickstart regeneration in degraded natural habitats, combined with protection of regenerating areas from livestock browsing or wood harvesting. The resulting increases in soil binding and canopy and ground cover could be beneficial for reducing erosion, particularly in areas with steeper slopes. Increasing the density of trees could also increase the supply of wood- and plant-based products and have positive impacts on biodiversity by providing corridors and habitat to species (RTI International, 2017, FAO, 2019). However, given evident high fuelwood harvesting pressures in the catchment, presenting tree planting as a means to increase fuelwood supplies could result in over-harvesting of regenerating habitats and thus undermine the success of the intervention.

Tree planting has already been conducted in the Mwache Dam catchment areas, and is a popular land restoration option in Kenya. However, several stakeholders interviewed were scathing about this, claiming that its popularity is due to its ease of reporting "progress", whereas its actual success was minimal. Due to minimal after care and selection of species which are not sufficiently hardy, a large proportion of trees reportedly die, rendering this activity a waste of resources. There were also concerns about the planting of non-native and invasive tree species, and the planting of trees in habitats that are not naturally woody (Bond *et al.*, 2019). Nevertheless, engagement with CDA suggests that they are aware of these issues and have made some efforts to revise their practices in conducting tree planting as a catchment rehabilitation intervention under KWSCRP-II. For example, Bendera (pers. com) reported that they now use hardy species which are resilient in the face of dry conditions and are not appealing to livestock. She also claims the species used are non-invasive, including exotic species like bamboo.

Vetiver grass provides a cost-effective land restoration and soil erosion control measure, and has seen increasing adoption in land rehabilitation efforts in the region. It has been promoted as an alternative to structural rehabilitation measures such as gabions and contour banks, which are more expensive and difficult to implement (Oshunsanya & Aliku, 2017). Vetiver grass strips are effective at slowing and reducing runoff and thus erosion on both cropland

and degraded land not under cultivation. Numerous studies have demonstrated erosion and runoff reductions of 50% or more (Oshunsanya & Aliku, 2017). Added benefits are its unpalatability to livestock and resilience to trampling, which should increase its likelihood of survival following planting. We propose the use of Vetiver grass as a form of bio-engineering to stabilize highly eroded, denuded areas in the catchment, such as gullies and bare areas around villages. Dense vetiver hedgerows have been used for this purpose elsewhere in Kenya, and it presents a cheaper alternative to built infrastructure interventions to stabilize heavily degraded areas.

Restoration of degraded riparian areas

Riparian replanting was proposed by RTI International (2017). It is generally advised that a buffer of 30 m from stream and river edges be established and that soils and vegetation in the buffer are left undisturbed as far as possible. Areas where excessive soil erosion has occurred has been suggested as the priority target for stream bank restoration. Approaches can include hard approaches such as constructing retaining walls and riverbank riprap walls. 'Softer' approaches suggested are bioengineering and replanting of vegetation. When rehabilitating and replanting riparian vegetation, it is again inadvisable to plant vegetation in the buffer zone that is not native to the specific locality.

Potential for application in the study area and estimated costs

We elected to use deforestation data from Global Forest Watch to identify potential sites for restoring tree cover. As noted earlier, this dataset can be used to identify areas which have experienced a decline in tree cover between 2001 and 2019, with the caveat that the methods are more suited to detecting changes in taller forest vegetation than in bushland. The change in woody biomass thus has to be fairly significant in order to be detected. Despite these limitations, the dataset has value for identifying areas which have experienced a relatively recent, detectable decline in woody cover. Approaches such as enrichment planting and ANR could be used to regenerate woody cover in such areas. We thus considered that such restoration approaches would be potentially suitable in all areas with natural land cover (forest, shrubland and grassland) that coincide with areas that have experienced a decline in tree cover according to Global Forest Watch. We excluded cultivated areas that coincided with tree cover loss, which presumably represent areas where woody cover has been replaced by agriculture. This is because we did not consider it feasible to convert currently cultivated areas back to cultivation, especially as there is not legal mandate to support this outside of protected areas or riparian zones. The costs of restoration can vary significantly, depending on factors such as seed availability, labour and the need for physical enclosures. Mechanisms to exclude livestock and discourage fuelwood harvesting will likely be needed in the catchment, particularly in areas with high human and livestock populations.

Drawing on studies of regeneration efforts in similar settings, we arrived at an establishment cost of $1000/ha for restoration of non-riparian areas. This includes inputs and labour for planting, compost/manure application and fencing to protect regenerating areas. Estimated maintenance costs are US$150/ha/year to cover management of growing seedlings, replanting where needed and repairs to physical enclosures.

Potential sites for riparian restoration were limited to within 30 m of watercourses. All riparian areas under non-natural land cover (cultivation or built-up), as well as areas with natural land cover that have experienced a decline in tree cover (as per Global Forest Watch) and/or degradation (measured by NDVI, as per Trends.Earth) were considered potential sites for restoration. In other words, we attempted to identify all riparian areas where natural vegetation has either been removed or degraded. Nevertheless, it is likely that the extent of riparian areas potentially requiring restoration has been under-estimated, as riparian degradation may often occur at too fine a scale to be detected in the datasets we used. Thus, field verification will be particularly important for identifying the final extent and nature of riparian interventions needed in the catchment.

As with restoration in non-riparian areas, riparian rehabilitation is a potentially expensive intervention which may requiring procuring and planting seedlings and fencing or other measures to exclude livestock and people. Given the extent of degradation of riparian areas in parts of the catchment, riparian rehabilitation has been costed slightly higher than rehabilitation of non-riparian areas. Thus, the estimated establishment cost for riparian rehabilitation is US$1300/ha, while annual maintenance costs were estimated to be US$195/ha (Table 5-2).

Table 5-2. Unit costs and potential extent of enrichment planting/ANR and riparian rehabilitation

Intervention	Establishment cost (US$/ha)	Ongoing costs (US$/ha/year)	Potential extent (ha)
Active rehabilitation (non-riparian areas)	1 000	150	1 655
Riparian rehabilitation	1 300	195	733
Total			**2 388**

Social acceptability and models of implementation

Rehabilitation measures, especially grass planting to stabilize severely degraded areas and those in protected riparian areas, will likely be among the most critical interventions from a water security point of view, but not benefit local communities materially. Apart from areas used for sand quarrying, these areas, which tend to be around villages, roads, old lands and cattle watering areas, are currently unproductive and will continue to be unproductive after rehabilitation. The rehabilitation of these areas will require teams of people who are trained and properly supervised. This provides an opportunity for employment of unskilled or semi-skilled labourers. This could be modelled along the lines of South Africa's NRM programmes, where people are employed to work on environmental restoration and provided with various skills in the process, and the work is managed by government employees, with emphasis on very manual methods and quantity of employees over efficiency. This model is not efficient, and has not always delivered environmental outcomes, however. Or it could be based on a competitive bidding process, where the work is put out to tender, and paid upon delivery. The latter is better, as it could incorporate some conditions and safeguards. For example, a portion of the payment could be held back contingent on the rehabilitation measures still being securely in place after a year. Either way, this will involve the preparation of very clear guidelines on how to do the work, and some sort of training for the teams engaged. Something will need to be done to control sand quarrying, which is a major driver of sand exposure and erosion.

SOIL EROSION CONTROL MEASURES ON CULTIVATED LANDS

Types of interventions and their potential efficacy

Cultivation leads to soil loss when soils are exposed during ploughing, after harvesting and when fields are fallow. The soil loss is usually mediated by rainfall, but wind can also play a role. Soil loss is potentially greater when soils have been loosened by ploughing, and when the cultivated area is on a steep slope. The potential for soil loss also varies with soil type, with a high amount of medium-sized particles (silt) generally being more susceptible than clayey and sandy soil. Sustainable land management (SLM) interventions to reduce soil loss in cultivated areas include the following interventions, most of which were also recommended by RTI International (2017) for the Mwache Dam catchment area:

- Reduced tillage to minimise soil disturbance, for example by using Zai-pits;
- Maintaining soil organic cover, e.g. by planting cover crops in non-productive seasons;
- Contour ploughing, terracing (e.g. *fanya juu*) and cross slope barriers to reduce soil loss on slopes;
- Agroforestry, including Farmer managed natural regeneration – to include and restore trees in and around fields

The first two of these are elements of what is known as "**conservation agriculture**". Conservation agriculture focuses on three key principles: minimal soil disturbance (i.e. no tillage), ensuring permanent soil organic cover (with crop cover and crop residues) and ensuring species diversity of crops through varied crop sequences and associations (FAO, 2021; Greener.Land, 2021). It includes several practices aimed at increasing productivity such as mulching, intercropping, manuring and seed improvement. Conservation agriculture tends to lead to an improvement in soil organic matter, which can greatly enhance productivity in low rainfall areas (Karuku, 2018). Crop rotation ensures good soil structure and soil biota which enhance nutrient cycling and reduce the likelihood of diseases and pests affecting crops (FAO, 2021). Measures pertaining to soil conservation are discussed in more detail below.

Reduced tillage

The reduction of mechanical soil disturbance through tillage via direct seed and/or fertiliser placement reduces soil erosion and ensures higher retention of soil organic matter (FAO, 2021). A common method is Zai pits, are 0.6 m diameter and 0.3 m deep pits in which seeds are planted. They are becoming more popular in arid and semi-arid areas (< 800 mm) in Kenya where they can simultaneously be used for soil conservation and growing crops with relatively high water demand, particularly when used in conjunction with fertilisers (Mati, 2006; Black *et al.*, 2012). Fodder planting pits (*tubukiza*) were also recommended by RTI International (2017).

Cover crops

Permanent soil organic cover (at least 30% coverage) can be achieved either through crop residues or cover crops. This ensures a protective layer of vegetation on the soil surface which supresses weeds, ensures higher water retention, reduces soil compaction and reduces the impacts of extreme weather on water and wind erosion (FAO, 2021). Growing multiple crops in the same field is already an important part of traditional farming systems in Kenya (Dallimer *et al.*, 2018). However, cover crops are not considered to be viable in most arid to semi-arid regions and were not listed in any of the previous studies for the Mwache Dam catchment. An exception is the planting of leguminous crops, which may grow in semi-arid to dry conditions. They are compatible with maize crops (Karuku, 2018), which are dominant in the Mwache Dam catchment. These can increase advance the process of soil fertility replenishment (Jama, Elias & Mogotsi, 2006). This can improve yields in areas with poor soil quality.

Contour ploughing, terracing and other cross slope barriers

The potential for soil loss from cultivated areas increases with slope. Contour ploughing, terracing and cross slope barriers all reduce the mobility of soil from cultivated lands. The simplest of these interventions is contour ploughing, which involves only ploughing and planting along contours, perpendicular to the normal flow direction of runoff (Panagos *et al.*, 2015b). This prevents the formation of erosion gulleys along vertical plough lines. On gentle to moderate slopes, contour farming alone can reduce erosion by around 40%, relative to ploughing across contours (Wischmeier & Smith, 1978). Terracing of fields further reduces erosion by leveling fields. Cross slope barriers intercept eroded soils before they move further downslope. These methods are best applied in combination within cultivated areas, and are broadly termed "*fanya juu*" in Kenya. Cross slope barriers can also be constructed below an area of several fields or denuded vegetation to prevent eroded soils from reaching river systems.

Fanya juu terracing has been widely practiced across Kenya since the 1950s, spreading rapidly under the National Soil and Water Conservation Program. It was originally promoted as a soil conservation technique and only later recognized as a useful water conservation method too (Black *et al.*, 2012). It is suitable in areas with a slope between 5% and 35%[21] and can reduce soil erosion by 30% or more (Tenge, De Graaff & Hella, 2005; Gathagu, Sang & Maina, 2018). *Fanya juu* is not technically demanding. The practice is common in many parts of Kenya with high levels of adoption and success (Thomas, 1997; Liniger *et al.*, 2011), particularly in the nearby Kitui and Machakos Counties (Black *et al.*, 2012). *Fanya juu* has also been shown to increase crop yields at study sites in the region, particularly when done in combination with additional inputs of manure and fertilisers (Mwangi, Mboya & Kihumba, 2001; Tenge *et al.*, 2005, 2011). Nevertheless, terracing is labour intensive in the establishment phase. Costs are generally recovered from about two years, with a positive long-term cost-benefit ratio (Ellis-Jones & Tengberg, 2000; Tenge *et al.*, 2011; Karuku, 2018).

Bench terraces are level or near-level platforms are an effective erosion control measure on steep slopes(>35% slope). At such high gradients, they ensure higher retention of soil moisture than other forms of terracing or cross slope barriers, at the expense of higher labour requirements (Tenge *et al.*, 2011). They can be made more effective with the addition of hedges[22] or planted trees as part of an agroforestry system (Liniger *et al.*, 2011; Karuku, 2018). However, due to the time-consuming nature of their construction, farmers tend to regard bench terracing as being labour intensive, especially as short-term crop yield benefits are low (Tenge *et al.*, 2011).

In addition to terracing, a variety of other cross-slope barriers can be used on farmland, particularly on gentler slopes. We propose the use of a number of measures here, including vegetative strips (*e.g.* using Vetiver grass), trash lines, stone lines and soil bunds (Liniger *et al.*, 2011), allowing for selection of the most appropriate measure(s) according to local conditions, expertise and farmer preferences. Collectively, these measures are best suited to gentler slopes (*e.g.* 5-12%) where full-scale terracing is unnecessary. In time, trapping of soil can lead to the formation of shallow terraces. Grass strips and other cross-slope barriers are thus often created as a first interim step in constructing bench or *fanya juu* terraces (Tenge *et al.*, 2011). The maintenance of these barriers is not insignificant; work is required to ensure gaps are filled and the strips remain dense or stones are aligned securely (Liniger *et al.*, 2011; Black *et al.*, 2012). Nevertheless, they are generally less labor-intensive to construct than terracing, while still making a significant contribution to reducing erosion. For example, Tenge *et al.*, (2011) found that grass strips reduced erosion by 80% on gentle slopes in the central Kenyan

[21] Linger et al. (2011) recommend slopes of 35% or less. However, Tenge et al. (2011) found fanya juu terraces to be 58% effective in slopes greater than 32% at two study sites measured.

[22] Hedges can additionally provide high quality fodder (such as lucerne), beans and other climbing legumes and firewood, and are useful for wind and soil loss protection (Karuku, 2018).

Highlands. Vetiver grass strips have thus been suggested as a more cost-effective and less labor-intensive alternative to terracing (Oshunsanya & Aliku, 2017).

Agroforestry and Farmer Managed Natural Regeneration

Agroforestry, where trees or shrubs are purposefully grown within or integrated with crops or pastures, can have both ecological and economic benefits, and is widely practiced in Kenya (Jama, Elias & Mogotsi, 2006; Liniger et al., 2011; Karuku, 2018). In drylands, agroforestry more typically involves using trees in various productive niches within a farm, rather than planting trees across whole farm plots. One of the key benefits is the potential to diversify livelihoods by creating additional food (for people and/or livestock) and income sources, reversing land degradation and improving land productivity through positive effects on soil structure and nutrient cycling. Some studies from Kenya and Ethiopia have also shown greater crop yields of certain types under tree canopies (Liniger et al., 2011; Karuku, 2018). Careful consideration needs to be paid to the species selected, given the harsh climate of the area. Additionally, there have been instances of planted fodder trees becoming invasive weeds (Karuku, 2018). If appropriate species are not used, agroforestry could suffer from the same criticisms already mentioned in relation to tree planting efforts – i.e. insufficient after care, including a failure to protect seedlings from livestock, and the use of species that are not sufficiently hardy to withstand dry spells.

Given the climate across much of the catchment is not suited to planting of fruit trees, planting hardy, palatable shrub species to serve as fodder banks for livestock could be a relatively practical form of agroforestry (Liniger et al., 2011). To maximise their erosion reduction potential, these can be grown along contours, or along plot boundaries to trap sediment leaving fields. If grown along plot boundaries, fodder banks have the added advantage of not competing for space with food crops, which is particularly beneficial on small plots (Liniger et al., 2011). Nevertheless, agroforestry may have at best a limited impact on erosion rates in the catchment if trees and shrubs are planted at low densities.

Farmer-managed natural regeneration (FMNR) can be thought of as a special form of agroforestry which involves the deliberate retention and systematic management of naturally regenerating indigenous vegetation on farmland (Liniger et al., 2011). It could also be an appropriate form of agroforestry for the catchment, as it is most commonly practiced in arid and semi-arid agropastoral areas (Chomba et al., 2020). Favoured species are those with deep roots which do not compete with crops (Liniger et al., 2011). As it takes advantage of natural regeneration abilities, the practice does not require expensive external seed inputs nor is it labour-intensive, making it appropriate for poor households (Ndegwa et al., 2017). Coppice regrowth can be pruned regularly, providing a source of fuelwood. It is thus a desirable intervention in areas with high harvesting of woody biomass. As FMNR species are adapted to harsh local conditions, they can also provide a valuable source of animal feed during dry periods (Ndegwa et al., 2017). In light of these strengths, FMNR has been noted as a strategy for improving woody cover in other studies of the catchment (RTI International, 2017; ESC, 2018b). However, the potential of FMNR is limited by whether there is sufficient availability of live tree stumps or remnant root and seed stocks to allow for regeneration (Liniger et al., 2011). It thus may have limited suitability in parts of the catchment where very little natural vegetation remains. The density of trees in FMNR systems also varies significantly (Chomba et al., 2020). Where farmers only permit low densities of regenerating trees, this practice is unlikely to have a substantial impact on erosion levels. However, it could have an indirect indirect impact through reducing harvesting pressures on remaining natural vegetation, thus helping to maintain protecting vegetation cover away from fields.

Potential for application in the study area and estimated costs

Cultivated areas in the catchment are concentrated in the eastern half of the catchment, as well as in the far west. We assumed that some combination of the proposed soil conservation interventions could potentially be applied to all cultivated areas. However, the nature of the proposed interventions varied according to gradients, as different interventions are appropriate for different slope classes. Land gradients in the Mwache Dam catchment are generally gentle to undulating, with a mean slope of around 4%. The area contained by the group ranches/conservancies of Taita-Taveta is the flattest area. Hilly terrain in the far west of the catchment, Kilibasi Hill and the immediate vicinity of the proposed Mwache Dam site are the steepest areas, commonly exceeding gradients of 10% (Figure 5-24). In the steepest areas of the catchment, above 12% slope, there is little farming activity.

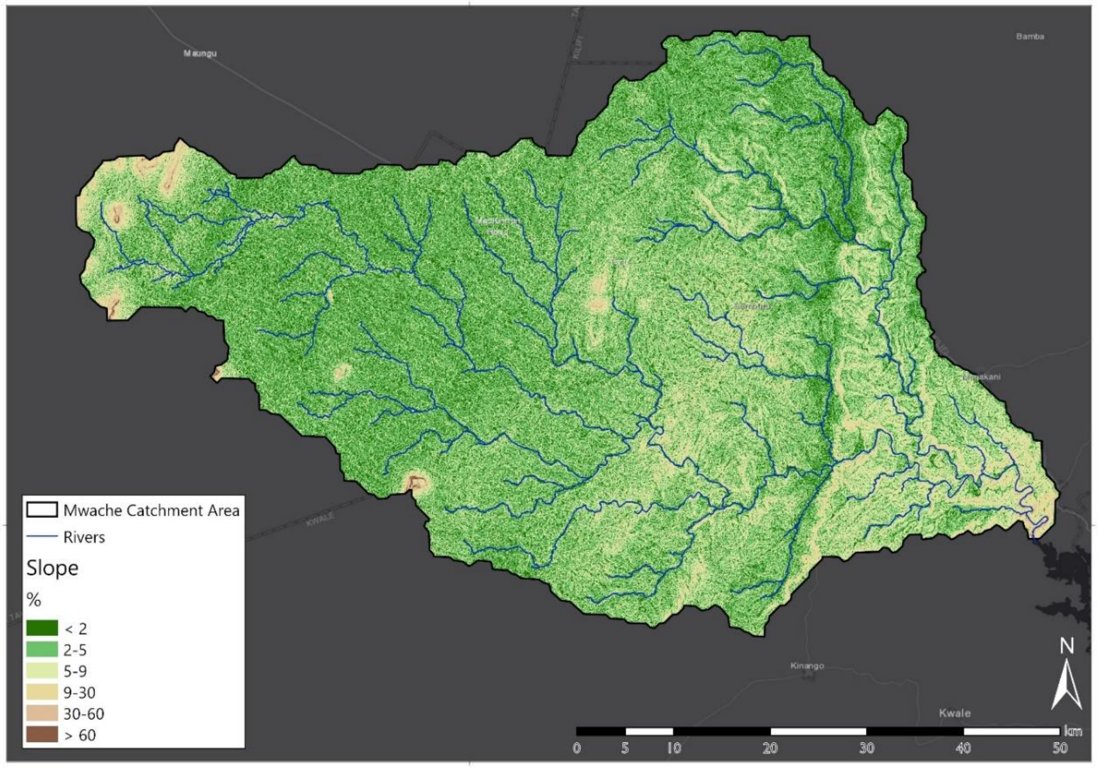


Figure 5-24. Map showing the slope/gradient of the Mwache Dam catchment. Slope derived from a digital elevation model using InVEST software.

For the purposes of mapping interventions, cultivated land was split into three slope classes. Different combinations of the soil erosion control interventions were proposed for each of these slope classes, as described below. Given the evident degree of overlap, SEC1, SEC2 and SEC3 can best be thought of as continuum of increasing intervention intensity as the gradient of cultivated lands increases.

SEC1 - Soil erosion control on flat cropland areas (<5% slope)

Areas with flat or very gentle slopes (<5%) do not warrant the construction of terraces or cross-slope barriers. Hence, a combination of contour ploughing, reduced tillage, cover cropping and agroforestry is proposed for cropland in this slope class. Due to the aforementioned possible challenges in the implementation of these interventions, we have not assumed all three will be applied in tandem in all cases. Rather, we hope that at least one of these interventions will be applied to the applicable areas, allowing for the final selection to be informed by the local context and knowledge. To account for this in our subsequent modelling of soil erosion control benefits, the expected impact of the three interventions was reduced relative to the optimal scenario where they are all fully carried out in combination.

The establishment cost for this intervention was estimated to be US$150/ha (Table 5-3). This incorporates the costs of extension services, training and demonstration, as well as the costs of additional inputs (*e.g.* seeds for cover crops) and potential additional labour requirements (planting or managing existing trees as part of FMNR, planting cover crops *etc.*). Annual maintenance costs were estimated to be low at around US$40/ha, reflecting the additional labour required to harvest or manage cover crops and/or agroforestry trees and the need for ongoing agricultural extension support.

SEC2 - Soil erosion control on gently sloping cropland areas (5-9% slope)

For cropland areas located on gentle to moderate slopes (5-9%), we proposed that the measures suggested for flat cropland (contour ploughing, reduced tillage, cover cropping and agroforestry) are combined with some form of cross-slope barrier (*e.g.* grass strips, trash lines, earth bunds). Such interventions are appropriate for reducing erosion on gentle to moderate slopes which do not warrant the construction of full-scale terracing (Liniger *et al.*, 2011).

The establishment cost for these interventions was estimated to be US$250/ha (Table 5-3), to account for the costs of agricultural extension and labour. This estimate is at the high end of the range suggested by Liniger *et al.*, (2011) (around US$40-270) thus providing a conservative estimate for the subsequent cost-benefit analysis (CBA), which could become more favorable if the intervention can be achieved at a lower cost. Maintenance costs were estimated to be US$65/ha/year, to cover activities such as maintaining grass strips, reinforcing bunds and replacing trash lines. This is again a relatively high cost estimate.

SEC3 - Soil erosion control on steeper cropland areas (>9% slope)

Terracing becomes increasingly effective and necessary in areas with steeper slopes. For this study, we propose that some form of terracing can potentially be applied to all cultivated areas on slopes with gradients above 9%. Based on the experience of CDA in the catchment (Bednera, pers. com) and its popularity in similar parts of Kenya, we assume terracing will generally be in the form of *fanya juu*. Again, we suggest that terracing is combined with other agronomic measures proposed under SEC1 (contour ploughing, cover cropping *etc.)*, as these measures in combination enhance the soil erosion control benefits of terracing (Thomas, 1997). Similarly, it is best practice to combine terracing with measures proposed under SEC2, such as growing grass strips on terrace bunds to further slow runoff and keep soil intact (Wickama, Okoba & Sterk, 2014).

Due to the higher labour requirements than the interventions proposed under SEC2, terracing was estimated to have an establishment cost of US$500/ha (Table 5-3). This incorporates the cost of labour, tools and equipment and inputs such as compost and seed for grass establishment. This cost estimate is based most closely on a case study from eastern Kenya where the establishment cost of grassed *fanya juu* terracing was estimated to be US$450/ha (Liniger *et al.*, 2011). Lower costs of terracing have been reported elsewhere, for example, just US$100/ha in western Kenya (Dallimer *et al.*, 2018). Hence, our cost assumption will once again be conservative in relation to the CBA of this measure. Annual maintenance costs for terracing was estimated to be US$80/ha, which is on the high side of the US$10-100 range reported by Liniger *et al.*, (2011). Maintenance costs include repairing and reinforcing terrace structures, as well as managing and reseeding grass in the case of grassed *fanya juu*.

Table 5-3. Unit cost and potential extent of proposed soil erosion control interventions on farmland

Intervention	Establishment cost (US$/ha)	Ongoing costs (US$/ha/year)	Potential extent (ha)
SEC1 on farmland	150	40	17 285
SEC2 on farmland	250	65	10 350
SEC3 on farmland	500	80	3 825
Total			**31 460**

Social acceptability and models of implementation

Interventions which seek to reduce soil erosion from farmland are key to the future sustainability of the dam, given the high export of sediment from agricultural lands. In addition to reducing erosion, there is the potential to benefit livelihoods through increasing crop yields due to the maintenance of soil fertility and increased rainwater retention. Household survey data revealed soil erosion to be the most widely noted form of land degradation in the catchment (ESC, 2018a). The high awareness of the issue bodes well for the acceptability of these interventions which aim to reduce soil erosion. Furthermore, some of the proposed interventions are already commonly practiced by Kenyan small-scale farmers (Dallimer *et al.*, 2018). In such cases, the goal of the water fund would be to further increase uptake of these more well-established practices.

Contour ploughing in theory should be relatively simple to implement, as it does not involve any major change in labour or equipment requirements. It is already widely practiced by smallholder farmers in East Africa (Fenta *et al.*, 2020), suggesting there should be no major barriers to increasing adoption of the practice in the catchment. Greater education and extension efforts, which emphasize the ability of contour ploughing to reduce soil degradation through mitigation erosion, should be helpful in this regard.

Reduced and no tillage approaches have not been widely adopted by Kenyan small-holder farmers, despite the benefits of these practices (Kaumbutho & Kienzle, 2007). For example, no-till conservation agriculture has been found to improve yields by 60% or more in other parts of Kenya (Liniger *et al.*, 2011). Crops can also be planted earlier, as the soil has to become moist before ploughing can commence when using conventional methods. This allows farmers to access markets when prices are still high. With appropriate equipment, conservation tillage is also less labor intensive. These livelihood benefits would all be of value to local people in the catchment. However, a lack of farming inputs presents a key challenge to use of this practice (Kaumbutho & Kienzle, 2007). While a standard hoe or planting stick to open holes for planting, this is very time-consuming. Ideally, hand-held jab planters or animal- or machine-drawn equipment are needed to penetrate the soil cover to place seeds (Liniger *et al.*, 2011). Furthermore, yield benefits tend to take a few years to materialise (Kaumbutho & Kienzle, 2007; Liniger *et al.*, 2011). Poor farmers might not be able to afford the risk of adopting a farming practice which requires such an investment without the guarantee of a positive outcome. Addressing the unavailability and cost of the equipment needed for conservation agriculture will likely require external funding. Such funding can also be used to establish field schools and projects which promote and educate farmers on conservation agriculture. Equipment purchased as part of these projects could then be shared among interested farmers, as has been done in other parts of the country (Kaumbutho & Kienzle, 2007). The initial success of local 'champion' farmers may also encourage others to adopt the practice.

Cover copping, particularly using leguminous species which are better adapted to semi-arid conditions, has been suggested as a way of reducing the extent of bare soil on farmland in the catchment. Growing multiple crops can enhance resilience, as risk is reduced in the event one crop fails (Thomas, 1997). This would be particularly beneficial to livelihoods in the study area due to generally unreliable rainfall and challenging conditions for agriculture. Multi-cropping with leguminous species could also have a positive impact on yields through enhancing soil fertility. Cost or unavailability of seed may be one factor that would hinder uptake of this intervention among local farmers. Hence, provision of free or subsidized seed in combination with education and demonstration programmes could be one way of increasing uptake. Increased labour requirements arising from the need to plant, manage and harvest cover crops could be another barrier to adoption (Liniger *et al.*, 2011). Hence, demonstration and education programmes may again be important to convince farmers that yield benefits are sufficient to warrant the higher labour burden.

Terracing and cross-slope barriers are an important intervention for reducing erosion in sloping land. The potential for these interventions to retain water and increase yields should also increase their attractiveness, particularly where these benefits are evident from demonstration sites and champion farmers. However, high investment costs and a lack of short-term benefits are key barriers to adoption. This is particularly the case for terracing, which tends to have a negative short-term cost benefit ratio due to the high labour requirements in construction. This challenge is accentuated by the lack of secure individual land tenure across much of the catchment, which could further reduce willingness to invest large amounts of labour. Hence, some form of support is likely to be needed to increase the uptake of terracing. Encouragingly, the experiences of CDA in implementing SLM interventions as part of the KWSCRP-II project indicate that *fanya juu* terracing is being increasingly well received by local farmers (Mwanasiti Bendera, CDA, pers. comm.). According to Benedera (pers. comm), local farmers who have been exposed to *fanya juu* have noted its ability to retain water and soil, and the differences in productivity between terraced and unterraced farms. The increased interest in terracing is reflected in how CDA's model for constructing *fanya juu* has evolved. Initially, the CDA came to farms and provided all labour for *fanya juu* construction. Currently, CDA provides 60% of the labour while the farmer does 40%, with plans to further increase the share of construction done by farmers in the future (Bendera, pers. comm). A similar model where teams of labourers construct terraces in partnership with local farmers could work well for continuing to increase the coverage of terraces under the MWF.

As noted above, the impact of agroforestry on soil erosion could be limited, especially if tree densities are low. Nevertheless, it could potentially yield some erosion benefits through increasing vegetation cover while providing livelihood benefits to farmers. FMNR in particular could be especially appropriate and appealing for poor households, as it does not require expensive external seed inputs or high labour investment (Ndegwa *et al.*, 2017). Uptake of the practice could be improved through extension and demonstration efforts to show its benefits, such as providing a source of firewood and a potential hardy fodder source for livestock. Furthermore, excess wood can be sold, providing a form of income diversification. In addition to FMNR, active planting of fodder banks along contours or farm boundaries was suggested as a possible agroforestry intervention. This option might be less acceptable to farmers due to the costs of acquiring seed and potentially more labour-intensive planting and maintenance. Nevertheless, planting of fodder banks could still be appealing from a resilience perspective for households with livestock. Indeed, the practice has seen increased recent uptake in Kenya and other East African countries (Liniger *et al.*, 2011). Developing local nurseries and providing farmers with seed may also help to improve the attractiveness of the intervention through reducing the input costs. Despite the potential benefits, there may still be reluctance to adopt the described agroforestry interventions. As trees take several years to grow, the lack of secure individual land tenure will be a serious disincentive to adoption in parts of the catchment (Liniger *et al.*, 2011). Furthermore, Dallimer *et al.*, (2018) found that the *perceived* yield benefits of agroforestry among Kenyan small-holder farms were relatively small, with interventions such as manuring, intercropping and terracing viewed as being more beneficial. Agroforestry may thus be a less attractive intervention for many farmers in the catchment, particularly where they bear the cost of purchasing inputs like seed.

In conclusion, the proposed interventions to control soil erosion on croplands have the potential to benefit farmers, and should be welcomed if they can be made and shown to work to the farmers' advantage. Good quality extension will be essential to ensure success and a measurable improvement in yield as well as reduction in soil loss. This may require a lot of assistance at first until there is proof of concept. Farmers can be asked to co-invest in these to ensure ownership and continued maintenance. Demonstrable successes will then encourage voluntary uptake among farmers if it is within their means. If there is no improvement in yield, then the farmers may require compensation for their efforts to prevent soil erosion. Alternatively, the requirement for terracing on steeper slopes can be made mandatory, but extension services would be required to prevent this from being retrogressive for farmers.

SUSTAINABLE NATURAL RESOURCE MANAGEMENT

Types of interventions and their potential efficacy

Sustainable harvesting

Loss of woody vegetation cover is a major problem in both the priority water source areas. The sustainable use of woody resources involves only utilizing the amount of material that can be replenished in a year. The sustainable yield is easy to determine, but limiting harvesting to this amount is difficult in a communal situation and impossible to achieve in an open access situation. This intervention therefore requires the establishment of secure property rights and incentives for cooperation. In areas of high importance for delivery of hydrological services, particularly water towers and riparian areas, strict protection may be necessary where there is a risk of failing to achieve cooperation. This is discussed in more detail in Part V.

Sustainable rangeland management

Overgrazing is a widespread problem in the study area, which leads to loss of vegetative cover and soil erosion. Sustainable rangeland management requires working within the ecological limits of the grazing system. This means determining grazing capacity and a suitable grazing strategy, such as rotational grazing or transhumance, which allow for livestock to be moved around in response to fodder availability. However, these livestock management strategies have been disrupted by increased human population densities, fragmentation of rangeland by cultivation and the individualization of land tenure (Ogutu *et al.*, 2016). They will thus have limited applicability in the more densely populated parts of the catchment. In these areas, more active restoration interventions may be required, such as planting to replenish cover of fodder species and physical enclosures to allow recovery of vegetation. While measures such as rotational grazing can be effective, a reduction in stocking densities may be the only way to meaningfully improve rangeland condition in others. However, this is difficult to achieve given the importance of livestock to livelihoods in combination with ongoing population growth. Because of this, some authors have proposed *increasing* stocking density by planting fodder crops. However, this requires significant knowledge to manage livestock and rotate it effectively, and carries a great risk (Karuku, 2018; Rural Focus Ltd, 2020).

Potential for application in the study area

In the absence of better data, we relied primarily on remotely sensed information on land productivity (as measured by NDVI) to identify potential locations for sustainable harvesting and rangeland management. Areas with natural land cover exhibiting a decline in NDVI were thus considered to be potential sites for this intervention. Declining NDVI in such areas reflects a decline in the productivity of vegetation, which could be the result of wood harvesting, overgrazing or a combination of both. Sustainable natural resource management in these areas could aid the recovery of vegetation to a healthier state, which will improve canopy and ground cover and thus reduce erosion. A caveat of this approach is that only land degradation since 2001 is picked up using the satellite record. Hence, the extent of degradation of natural habitats is likely to be much greater, as areas that were already degraded by 2001 would be missed. Nevertheless, it could be argued that interventions should focus on more recent degradation, since it may be easier to aid recovery here than in patches of natural vegetation which have been in a degraded state for decades.

For costing purposes, potential areas for sustainable natural resource management approaches on group ranch/conservancy areas, which are characterized by extensive land use and low population densities, were separated from potential areas located within the remainder of the catchment which is characterized by small-scale farmland. This is to account for the likely differences in the nature of these interventions across these two land use categories, with a need for more intensive management in the more densely populated, small-scale farming areas. For example, there could be a greater need for more active interventions like fencing and re-seeding in the latter areas. Thus, we have assumed establishment costs of US$500/ha/year with ongoing (extension) costs of US$75/ha/year in the small-scale farming areas (Table 5-4). In the group ranch areas, estimated costs for this intervention were US$250/ha/year with ongoing (extension) costs of US$35/ha/year.

Table 5-4. The potential extent and costs of sustainable natural resource management interventions in the small-scale farming and group ranch/conservancy areas

Intervention	**Establishment cost (US$/ha)**	**Ongoing costs (US$/ha/year)**	**Potential extent (ha)**
Sustainable natural resource management (group ranch/conservancy areas)	250	35	18 711
Sustainable natural resource management (small-scale farming areas)	500	75	17 252
Total			**35 963**

Social acceptability and models of implementation

There has already been a significant shift in rangeland management across much of the western part of the catchment, where former livestock group ranch areas have adopted conservation as a land use in forming the Tsavo Conservancy. While the long-term acceptability of this change in land management is yet to be seen, it should alleviate livestock pressures across the large parts of the catchment which fall within the conservancy.

In more densely populated parts of the catchment, other livestock management interventions will be needed, particularly where overgrazing has contributed to poor vegetative cover and erosion. Although sustainable rangeland management leads to greater productivity, implementing measures to limit livestock numbers is not popular, given the cultural importance of livestock (Karuku, 2018), which determines that quantity is generally preferred over productivity. Severely degraded pasture areas may require fencing or at least some form of community agreement to avoid grazing. However, this will likely be difficult to implement in more densely populated parts of the catchment where grazing land is scarce. Where possible, re-seeding grasses and/or planting of fodder trees/shrubs will likely be a more acceptable intervention. Due to land scarcity, local farmers could be encouraged to plant forage species along plot boundaries, or integrate them into vegetative strips, the bunds of terraces and other soil and water conservation measures. FMNR could also be pursued as a way of increasing fodder availability where possible. As with other interventions, increasing acceptance of these measures will likely require channeling of funds into education programmes and demonstration plots.

Restoring and maintaining grass and woody vegetation cover in communal land areas will benefit resource users in the long run (after several years) but may meet with resistance because of the short-term opportunity costs. Action (sustainable rangeland management, sustainable woody resource use, environmentally-sensitive land use planning for settlements and cultivation) will not be achievable without incentive measures. Incentive measures, in turn, will not achieve any results without clear property rights. With clear property rights, land management should already improve. However, the way in which property rights are assigned matters. For grazing systems, a grazing intervention can work as long as the area to be shared is sufficiently large to allow for some degree of rotation and even transhumance in response to seasonal or interannual variation in rainfall. This requires cooperation between village areas and largescale grazing management. It also requires some sort of grazing permit system, preferably a cap & trade system in which herd numbers are capped according to conditions. At a more local level, achieving natural regeneration and maintaining woody cover could be incentivized if a defined community, responsible for a defined, not too large area, is rewarded in line with the state of its vegetation cover. This area can be part of a larger grazing cooperative, and would have the incentive to ensure that rules are not broken in its area. It should also have the power to issue wood cutting permits and sanction those who use wood without them, with heavier sanctions in riparian zones. These communities need to already exist or be willing to work together. They need to be formalized, with the help of the county governments. The payments for ecosystem services need to reach a significant number of households in the community and need to be worthwhile. The way to make it work better, would be for households to earn through active patrol and monitoring activities. This avoids the conundrum of trying to reward everyone equally when they are not contributing equally, which will doom a system to failure faster than one in which people moan that its not fair. Those moaners are often the free riders or system cheaters. Here it also needs to be pointed out that it would be a good idea to include the conservancies in the PES scheme, and to pay them the most. This would show that having good vegetation cover reaps rewards, will encourage the conservancies to keep doing what they are doing, and provide a real incentive for other communities to work towards or even to form conservancies. Community areas need to be defined. These should align with existing sense of community and small enough that people know one another. But so that all land is within community areas, and that these communities have representation. Then set up cooperatives – a group of community areas that work together as large grazing areas like a conservancy.

CONSERVATION OF IMPORTANT NATURAL AREAS

Types of interventions and their potential efficacy

The most effective and sure means to recover and maintain the health of vegetation and secure the supply of ecosystem services in catchment areas is through the protection of parts of the catchment in protected areas or community wildlife conservation areas, with the proviso that the *management* of these areas is effective.

Protected areas and conservancies

Increasing the area under protection can be done through the declaration of new state protected areas, or through the establishment of conservancies that are set up for wildlife-based land use. This is most feasible in areas that are marginal for farming, such as those on steep slopes (> 12%, RTI International, 2017), or that are close to other protected areas, which facilitates wildlife colonization and where there is already some tourism infrastructure.

The establishment of private or communal conservancies is likely to be more viable than state protection. Kenya's conservancy model (initially the Porini Model) was developed in the 1970s. Communities were incentivised to conserve wildlife and habitats by providing them with sustainable livelihood benefits such as ecotourism income from adjacent protected areas and the establishment of sustainable ranching methods (Ngaja, 2018). Conservancies have been covered over 6.3 million ha or 11% of Kenya's surface area by 2016 (KWCA, 2016), and are widely regarded as being a successful model for effective conservation (Ngaja, 2018; Riggio *et al.*, 2019). The conservancy model is best suited to large areas of low population density with few fences and barriers. Increasing the area under conservancies would require some incentive and/or assistance in setting up. According to Ogutu *et al.*, (2016), the relatively new Wildlife Conservation and Management Act 2013 promotes private and community conservation and provides a framework within which communities can be empowered to use, manage and receive increased economic benefits from wildlife. Among other provisions, the act calls for wildlife conservation to be devolved to land owners and managers as far as possible, and that benefits of wildlife conservation should go to land owners. Notably, the Act explicitly states that a wildlife conservation order or easement can be created to "preserve the quality and flow of water in a dam, lake, river or aquifer", indicating clear legislative support for conservation easements in the catchment. However, the absence of wildlife could limit the applicability of this act over much of the catchment. Where commercial ventures exist (although limited in the study area), tax incentives are potentially useful for attracting buy-in into conservancy models.

Riparian protection

Riparian areas are a priority for protection, but the protection of longitudinal areas is particularly challenging. The increased protection of buffer / riparian areas is likely to have some of the best long-term benefits for soil and water conservation. Riparian areas are usually characterised by relatively dense vegetation, often with large, evergreen trees, in sharp contrast to the surrounding upland vegetation (Monadjem, 2005; Monadjem & Reside, 2008). These areas not only have relatively high biodiversity value but fulfil numerous ecosystem numerous ecosystem services critical to ecosystem functioning within and beyond the riparian boundary, and of benefit to humans (Naiman & Décamps, 1997; Soman *et al.*, 2007; King & Pienaar, 2011). Riparian vegetation aids in trapping upland pollutants, fertilisers, sediments, wastewater and pesticides, preventing their transport to areas downstream (Gilliam, 1994; Hood & Naiman, 2000; Naiman *et al.*, 2005; Soman *et al.*, 2007). People living near riparian areas or in lower reaches of catchments benefit from riparian zones; hydrological control by intact vegetation and absorbent soils mitigate flooding and are usually the least impacted ecosystems in severe drought, often buffering the effects on other systems downstream (Clarke, 2003; Scholes, Bond & Eckhardt, 2003; Naiman *et al.*, 2005). The benefits of intact riparian zones are clear and well understood and thus their protection goes a long way towards enhancing water supply and reducing sedimentation, particularly in a semi-arid environment.

Potential for application in the study area

The coverage of state protected areas in the catchment is minimal. A small portion of Tsavo East National Park falls within the northern boundary of the catchment, as does a part of the Mailuganji Forest Reserve in the southwest corner of the catchment. However, relatively extensive parts of the western part of the catchment in Taita-Taveta are under conservation in the form of conservancies. These currently maintain good vegetation cover, provide opportunities for wildlife tourism and improve connectivity between Tsavo East and West National Parks. Low population density, conditions which are too dry for agriculture, intact natural habitats and land tenure in the form of extensive group and private ranches have all facilitated the establishment of conservancies here.

Potential sites for new conservation areas were identified based on the distribution of areas of woodland, shrubland and forest[23] extracted from the land cover map. Contiguous areas in excess of 100 ha were isolated in order to ensure a minimum threshold area of 100 ha for implementation, and areas within 1 km of a road were excluded. A boundary clean was conducted on the areas which "smoothed" the areas to more viable areas that could actually be implemented (rather than square pixels). In reality subsets of these areas and potentially other land cover types may be included. Hexagonal 'planning units' were applied to the catchment to make spatial planning for conservation more practical. These are 1 km^2 each and any planning unit which overlapped at any point the potential conservation areas were considered a possible area for implementation. These therefore represent the *maximum* possible conservation units possible.

The mapping exercise resulted in 62 188 ha of potential community conservation areas across the catchment, or 1 385 planning units (Figure 5-25). Most potential areas for conservation are in Kilifi and Kwale Counties, as natural vegetation in Taita-Taveta is now largely already under conservancy or national park protection. Importantly, the identified areas are mostly too small and isolated to support large wildlife, which could reduce their appeal from a tourism perspective, as well as their eligibility to receive conservation easements under the provisions of the Wildlife Conservation and Management Act 2013. However, a potential exception is in the far north of the catchment, where a largely contiguous area of natural vegetation exists in close proximity to Tsavo East National Park. The cost of this intervention would include the transaction costs needed to designate specific areas of the catchment as community conservation areas through public participation processes and negotiation. This is estimated to be US$1.50 per ha (based on Wise *et al.* 2012). Ongoing management costs would include the costs of policing, training and equipment to support community guarding programmes, and were estimated to be US$43/ha/year.

[23] Areas identified as grassland in the land cover dataset were excluded as these generally reflect fallow/abandoned fields or wooded areas that have been denuded by wood harvesting

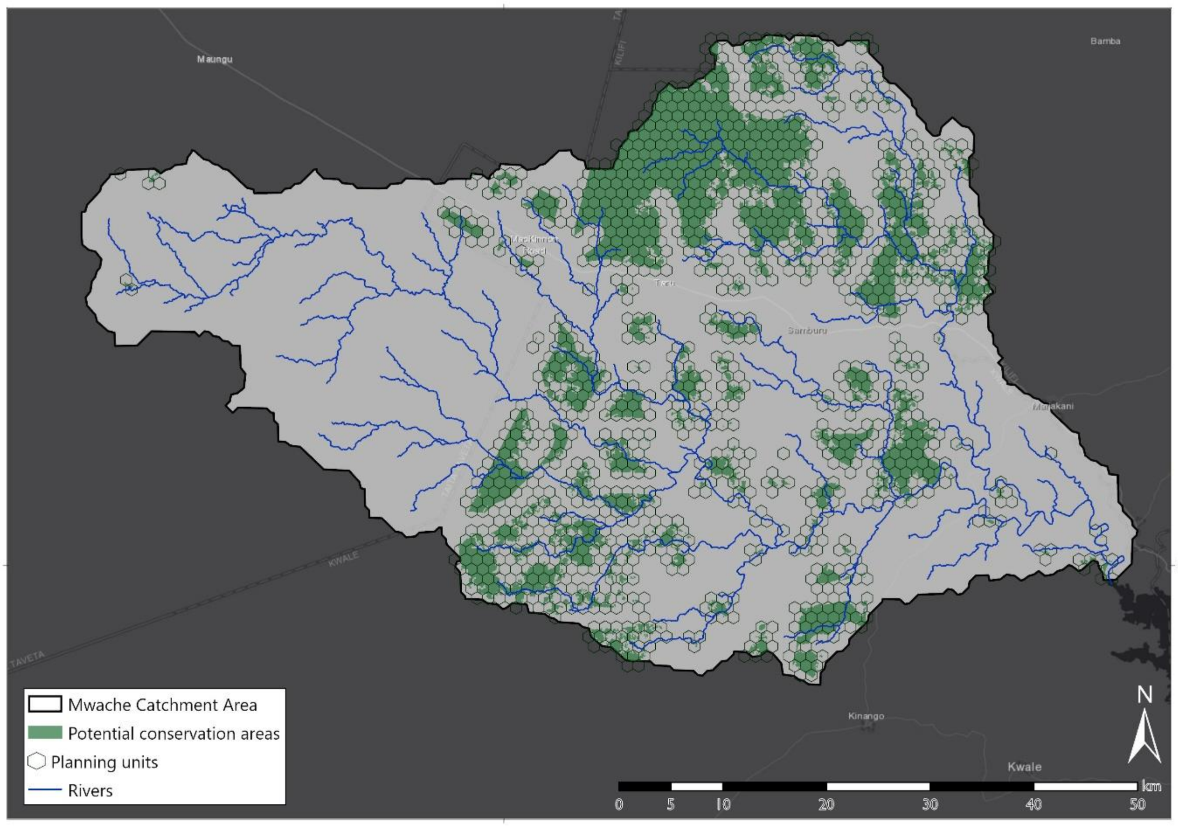


Figure 5-25. Potential areas for community conservation areas in the Mwache Dam catchment based on desktop-analysis using land cover as a determining factor.

In theory, riparian protection should be implemented across all riparian buffer areas in the catchment. For this study, we have assumed a riparian buffer size of 30 m from watercourses. Areas just requiring protection are separated from riparian areas which also require rehabilitation. As noted earlier, riparian rehabilitation was mapped for all riparian areas under non-natural land cover (cultivation or built-up), as well as areas with natural land cover that have experienced deforestation (as per Global Forest Watch) and/or degradation (measured by NDVI, as per Trends.Earth). Riparian protection was considered to be sufficient for all remaining riparian areas which did not meet these criteria. This would involve the clear demarcation and enforced protection of the riparian areas through policing, an activity that can be provided by community guards. Based on projects carried out elsewhere in Kenya and the region, ongoing protection of these areas through a community guard programme was estimated to cost around US$43/ha/year (Table 5-5).

Table 5-5. Unit costs and potential extent of new conservation areas and riparian protection

Intervention	Establishment cost (US$/ha)	Ongoing costs (US$/ha/year)	Potential extent (ha)
New conservation areas	1.50	43	61 178
Riparian protection	1.50	43	5 944
Total			67 122

Social acceptability and models of implementation

The development or expansion of state protected areas is likely to be a less appealing option to communities and land owners in the catchment, as it would involve ceding their land ownership and resource use rights to the state. Voluntary formation of private or community conservancies is thus likely to be a more socially acceptable intervention. As noted above, the development of conservancies in the catchment can be located within the provisions of the Wildlife Conservation and Management Act 2013, which includes provision for conservation orders and easements which help preserve the quality and flow of water into dams. The Act allows for parties to a voluntary easement to negotiate appropriate compensation for any loss of land value resulting from creation of the easement. To increase awareness of these opportunities, education and sensitisation of the benefits of participation in conservation may be required and is recommended. The attractiveness of conservancies as a land use could ultimately depend on the current performance of agriculture and livestock ranching. For example, the poor performance of cattle ranching is said to have encouraged the adoption of the conservancy model in Taita-Taveta. The risk of increased human wildlife conflict (HWC) could be a significant reservation around the development of conservancies. Communities might thus need to be assured of sufficient compensation for costs suffered as a result of HWC. Communities will also likely need assistance and capacity-building to enter into negotiations regarding appropriate compensation for conservation easements. They may also require assistance with meeting the requirements stipulated in the Act concerning applications for the registration of community conservancies (*e.g* documenting wildlife resources, describing proposed management and monitoring activities *etc.*). Conservation NGOs with an interest in improving conservation in the region could play an important role in educating and assisting communities in this regard. The County Wildlife Conservation and Compensation Committees (CWCCCs) will also have a role to play in conservancy establishment. Among other relevant functions, the Wildlife Act states that CWCCCs are responsible for harnessing the participation of all relevant stakeholders in planning and implementing wildlife conservation projects, overseeing the preparation of management plans for community and private conservation land and implementing the registration and establishment of wildlife user rights. National-level institutions such as the KWS and KFS will also likely be supportive of efforts to further develop conservancies, given their potential role in conserving wildlife and forest resources. Conservancy creation in the study area would be of particular interest to KWS, as it has the potential to further improve the conservation status of buffer zones around Tsavo East National Park.

Conservation of riparian areas is supported by the law in Kenya, including regulations which state that rivers have a protection zone of at least 30 m from the highest water mark (Nzau *et al.*, 2018). However, smallholder farmers in Kenya are often not aware of rules and regulations regarding riparian zones (Nzau *et al.*, 2018). Furthermore, various reasons may attract local people to settle along rivers, including fertile soils and groundwater availability. As much of the Mwache Dam catchment is characterised by water scarcity and poor soils, riparian areas often hold the only fertile land and they have thus become key areas for supporting agricultural livelihoods in the area (Bendera, pers. comm). Farm size is another factor which might reduce the acceptability of interventions in the riparian zone. Farmers with small land parcels which encompass the riparian zone may be unwilling to spare some of their land for protection or rehabilitation (Nzau *et al.*, 2018). Hence, despite legal backing, there is likely to be much resistance to protection and rehabilitation of riparian buffer zones in the catchment, particularly from farmers practicing cultivation in this zone. In general, there appears to be a clear need for improved awareness and understanding of the need for riparian zone conservation and the rules and regulations which underlie it. Unfortunately, government regulatory agencies and environmental officials lack the resources to enforce rules regarding riparian buffers, while local smallholders may negatively perceive the advice they provide (Nzau *et al.*, 2018).

Given the high resistance to protecting riparian areas and their importance to livelihoods, a pragmatic approach might be to pursue interventions which improve the health of the riparian zone while also providing sone livelihood benefits. For example, CDA has been encouraging farmers to plant bamboo in riparian areas in combination with value chain addition and sensitizing communities to the value of bamboo (Bendera, pers. comm). Bamboo is reportedly valued in the catchment due to the shortage of wood for poles, housing and other purposes. While bamboo might not have high biodiversity value relative to the original riparian vegetation, it does offer better erosion protection and soil stabilization than crops. It may thus provide a more pragmatic solution to reducing erosion in riparian zones, relative to attempting to exclude all livelihood activities from riparian zones and restore riparian vegetation back to its original state.

SUITABLE AREAS FOR SELECTED ENVIRONMENTAL MANAGEMENT MEASURES

The criteria used for mapping suitable areas of the various interventions is summarized in Table 5-6, while a map showing the resulting potential coverage of the interventions is shown in Figure 5-26. As can be seen in the map, potential areas for soil erosion control interventions on cropland are mostly located in the eastern half of the catchment as well as in the far west, reflecting the mapped distribution of cropland in the land cover data. As slopes are mostly gentle in the catchment, SEC1 and SEC2 are more widespread than SEC3, with the latter mostly limited to steeper areas in the far west and lower eastern reaches of the catchment. Large areas with the potential for sustainable rangeland management exists in the west of the catchment, though some opportunities also exist in the eastern half. Potential new conservation areas are scattered across the eastern half of the catchment. However, the largest continuous blocks of unprotected, relatively natural habitat are found in the north of the catchment. Due to their smaller potential extent, the other interventions are harder to discern on the map when zoomed out at the scale of the whole catchment, especially the riparian interventions. The most sizeable potential areas for enrichment planting and ANR are located around Mount Kasigau in the southwest corner of the catchment.

Table 5-6: Criteria for mapping the potential location of the different proposed interventions

Intervention	Criteria
Community conservation areas	Currently unprotected areas with relatively contiguous coverage of shrubland and/or forest
Riparian rehabilitation	Riparian areas (within 30 m of watercourses) under non-natural land cover and/or with tree cover loss and/or with a decline in NDVI
Riparian protection	Riparian areas (within 30 m of watercourses) that do not meet criteria for rehabilitation
Active rehabilitation (non-riparian areas)	Non-riparian areas still under natural land cover which have experienced a decline in tree cover
SEC1 on cultivated land	Cultivated areas with slope <5%
SEC2 on cultivated land	Cultivated areas with slope 5-9%
SEC3 on cultivated land	Cultivated areas with slope >9%
Sustainable natural resource management	Non-cropland areas exhibiting a decline in NDVI (*i.e.* degradation)

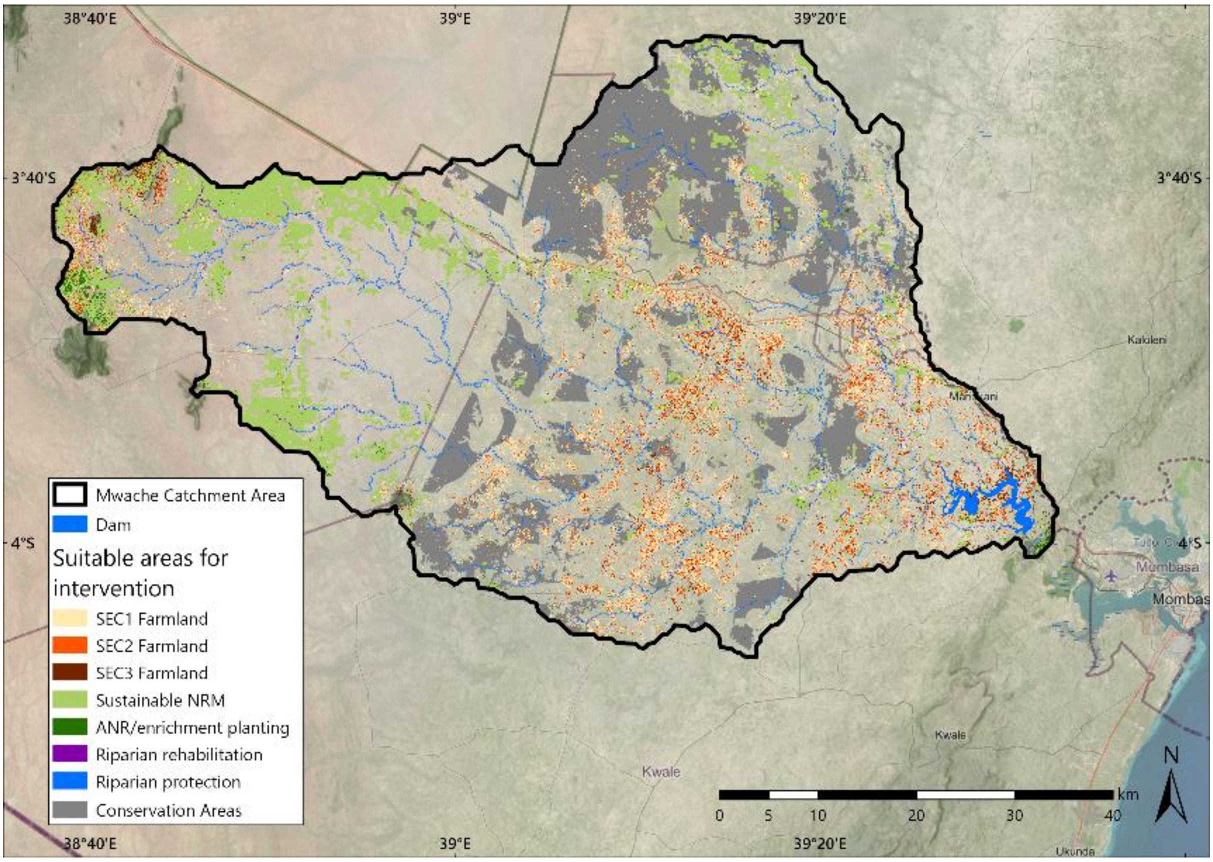


Figure 5-26. Map of suitable areas for the selected environmental management measures

The total potential coverage and cost of each intervention is shown in Table 5-7. The overall establishment cost of carrying out the interventions to their full potential extent is around US$23.1 million, with ongoing yearly costs of US$6.9 million.

Table 5-7: Total areal extent and costs if proposed interventions are carried out across all suitable areas

Intervention	Full extent (ha)	Establishment / setup cost (US$)	Ongoing cost (US$/y)
SEC1 on cultivated land	17 285	2 593 000	691 000
SEC2 on cultivated land	10 350	2 588 000	673 000
SEC3 on cultivated land	3 825	1 912 000	306 000
Sustainable resource management	35 963	13 304 000	1 949 000
Active rehabilitation (non-riparian areas)	1 655	1 655 000	248 000
Riparian rehabilitation	733	953 000	143 000
Riparian protection	5 944	9 000	253 000
Community conservation areas	61 178	92 000	2 600 000
Total costs		**23 105 000**	**6 863 000**

DETERMINING A COST-EFFECTIVE PORTFOLIO OF INTERVENTIONS

OVERVIEW

It is unrealistic to expect interventions will be carried out in every potential area, given the size of the areas and costs involved in doing so. Furthermore, even though an area might be potentially suitable for intervention, doing so might have a limited impact on sediment export, thus generating a poor return on investment. The next component of the analysis thus attempts to identify optimum locations for the proposed interventions, which will yield the highest erosion reduction benefits for the level of investment required.

Determining a cost-effective portfolio or suite of interventions firstly required a baseline estimate of the current rate of sediment export per ha. This was followed by estimating sediment export rates from a hypothetical restored landscape where all proposed interventions are carried out across all potential areas. This required estimating the effects of the interventions mapped above on soil erosion parameters, and the production of a new land cover layer to reflect conditions if all interventions are carried out to their full potential extent. We then calculated the difference in sediment export between the current and hypothetical fully restored landscape on each pixel in the catchment. Finally, the layer containing the difference in sediment export between the current and fully restored landscape was used in an optimisation analysis to determine in which localities the interventions would be most effective, on the basis of their return on investment. The latter could be expressed in physical terms – i.e. the amount of sediment saved per US$ per ha.

Sediment export from both the current and fully restored landscape was modelled using the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) Sediment Delivery Ratio (SDR) model. For modelling current sediment export, the only modification made to the land cover was burning in the proposed location and extent of the dam. Although we use a similar model to the Physiographic Study, our analysis arguably provides an update to this study, having revised some of the assumptions and parameters used, while utilizing a more recent land cover dataset which appears to capture conditions more accurately in the catchment. The optimization analysis was carried out using the spatial Restoration Opportunities Optimization Tool (ROOT). Further detail on the process for determining the cost-effective portfolio of interventions is provided below.

CURRENT EROSION AND SEDIMENT EXPORTS

The physiographic study estimated where the erosion hotspots are likely to be, based on land cover, rainfall, slope and soil type (RTI International, 2017). It also ranked the 21 sub-catchments by their potential contribution to reservoir sedimentation, taking proximity to the dam site into account. As would be expected, several sub-catchments in the lower eastern reaches of the dam catchment ranked highly for sedimentation risk (Figure 5-27). Certain sub-catchments in the upper reaches of the dam catchment, which drain hilly areas with elevated erosion risk, also ranked relatively highly (RTI International, 2017).

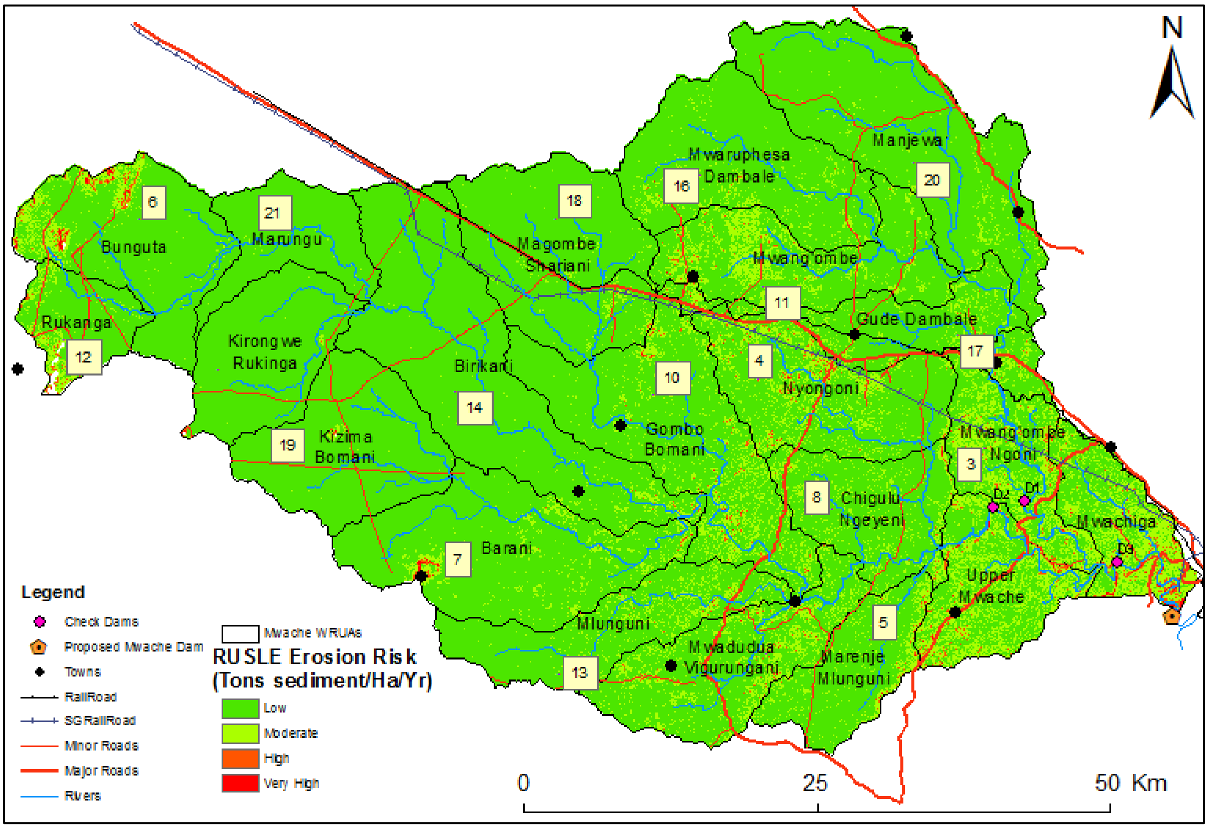


Figure 5-27. Ranking of sub-catchments by sedimentation risk posed to the Mwache Dam (lower numbers mean higher risk) (Source: RTI International, 2017).

For this study, we conducted our own modelling of sediment export using the InVEST SDR model. This model was selected as it generates pixel-level maps of sediment export at the spatial resolution of the input datasets used (20 m in this case). The model uses the revised universal soil loss equation (RUSLE) to estimate annual soil erosion across the region of interest. It then uses a pixel-level sediment delivery ratio and connectivity index to estimate the amount of eroded sediment which ends up in watercourses. The sediment delivery ratio component represents an improvement over the Physiographic Study (RTI International, 2017), which used a purely RUSLE-based approach and thus assesses soil erosion rather than sediment delivery *per se* (*i.e.* the amount of eroded soil which actually reaches watercourses).

Various parameters and input layers are required for the RUSLE component of the InVEST SDR model. The rainfall erosivity (R) component of the RUSLE equation is a measure of rainfall erosion potential, and is a function of the intensity and duration of rainfall events. In the absence of locally specific data, we used the Global Rainfall Erosivity Database (GloREDa) (Panagos *et al.*, 2017). The soil erodibility (K) component of the USLE equation is a measure of the susceptibility of soil particles to detachment and transport by rainfall and is a function of various soil properties. This was calculated from soil property layers obtained from the International Soil Reference and Information Centre (ISRIC) SoilGrids database (de Sousa *et al.*, 2020), using the monograph proposed by Wischmeier & Smith (1978). The land cover management (C) component of the RUSLE equation accounts for how different land cover types affect soil erosion relative to bare fallow areas (Wischmeier & Smith, 1978). C-factors were assigned to each land cover class in the catchment through consultation of various studies from the East African region and beyond (Wischmeier & Smith, 1978; Angima *et al.*, 2003; Hessel & Tenge, 2008; Panagos *et al.*, 2015a; Fenta *et al.*, 2020). In addition, the C-factor for cropland was adjusted using the proportion of farmers in the catchment employing conservation tillage and cover cropping, as reported in the Options Study (ESC, 2018a). Estimates of the impact of the relevant cover management practices on the C-factor for cropland in the catchment were derived from relevant literature (Roose, 1996; Angima *et al.*, 2003; Hessel & Tenge, 2008; Panagos *et al.*, 2015a). Finally, the support practice (P) factor of the RUSLE equation is relevant to agriculture lands primarily, and account for the reduction in soil loss through the implementation of structural soil conservation measures. Again, the P factor for cropland was calculated using the proportion of farmers reported to be using various structural soil conservation measures in the Options Study (ESC, 2018a). P factor values associated with the various soil conservation interventions were drawn from relevant literature (Tenge *et al.*, 2005; Hessel & Tenge, 2008; Wickama *et al.*, 2014; Panagos *et al.*, 2015b; Fenta *et al.*, 2020). The final C- and P-factor values used for each land cover class are shown in Table 5-8.

Table 5-8. Cover Management (C) factor and Support Practice (P) factor values for each land cover class

Land Cover Class	Cover Management (C) Factor	Support Practice (P) Factor
Forest	0.005	1
Degraded forest	0.08	1
Shrubland	0.12	1
Degraded shrubland	0.25	1
Grassland	0.15	1
Degraded Grassland	0.3	1
Crop	0.346	0.79
Aquatic vegetation	0.002	1
Bare	0.4	1
Built-up	0.3	1
Water	0	1

The estimated rate of sediment export from the InVEST SDR model is shown in Figure 5-28. The same information is also shown in Figure 5-29 but is aggregated to give average sediment export per sub-catchment. Total export of sediment to watercourses in the catchment was estimated to be 683 000 t/year, or an average of 1.88t/ha/year. However, sediment export rates vary significantly across the catchment. Steep slopes are associated with high erosion rates, such as in the far west of the catchment, as well as areas in the lower eastern reaches of the catchment, including around the dam site. Relatively high erosion rates are also evident in the southern central parts of the catchment which has been extensively cultivated. In contrast, erosion rates are low across most of the western half of the catchment due to generally intact vegetation cover and flat terrain.

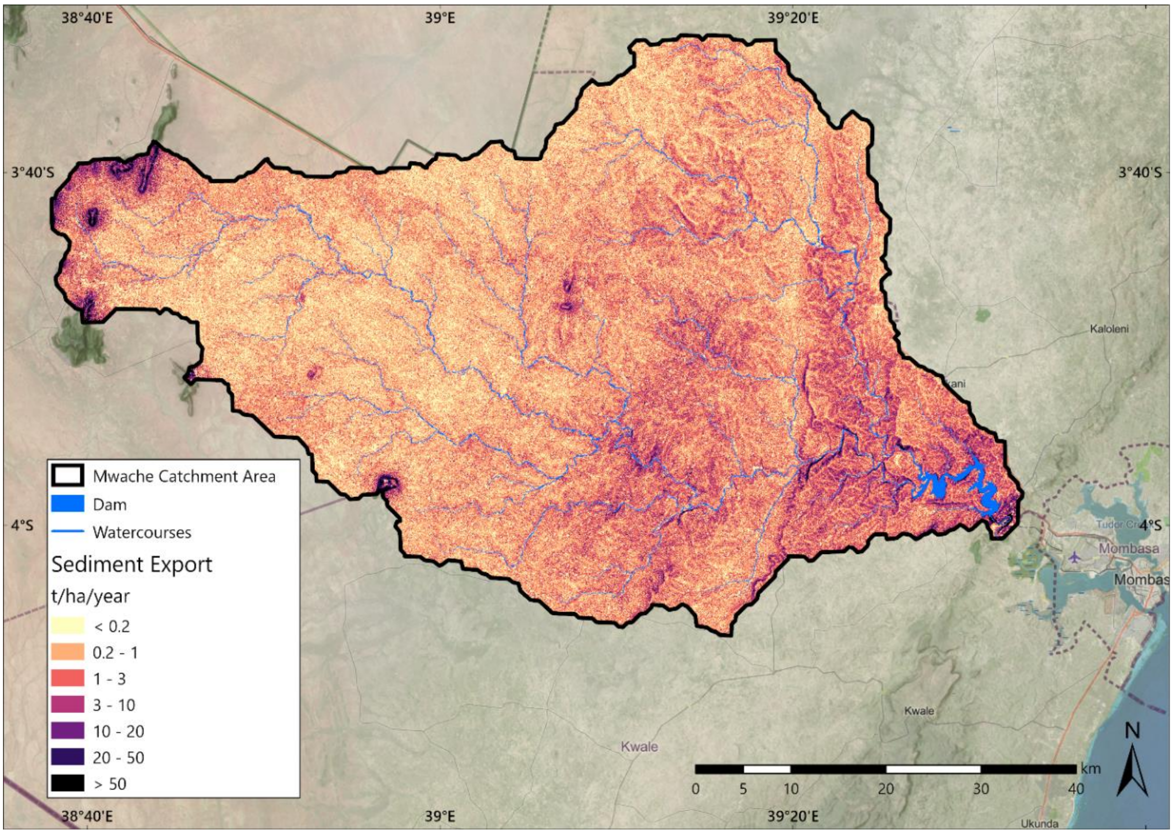


Figure 5-28. Estimated sediment export from the InVEST SDR model for current land cover

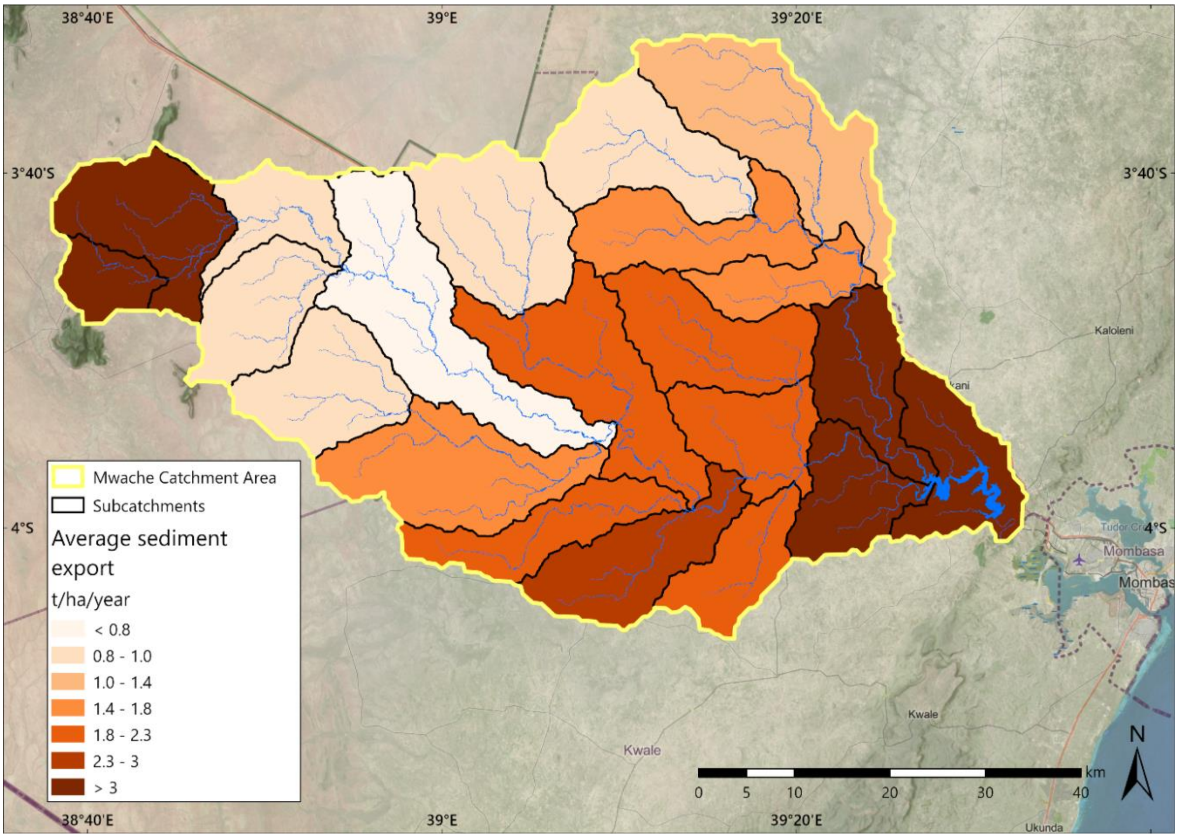


Figure 5-29: Average sediment export per sub-catchment from the InVEST SDR model for current land cover

Average sediment export rates across the different land cover classes in the catchment are shown inFigure 5-30. Sediment export ranges from a low of 0.13 t/ha/year in forest to 5.59 t/ha/year in areas classed as bare. Average erosion from degraded grassland was only marginally lower at 5.57 t/ha/year. Average sediment export was relatively low in shrubland (1.08 t/ha/year) but more than double this in degraded shrubalnd (2.57 t/ha/year). Sediment export from grassland (undegraded) was around 2.03 t/ha/year. Degraded forest had relatively high sediment export (2.36 t/ha/year) whch can be explained by the fact forest in the catchment tends to occur on hills, resulting in high erosion rates when the original forest cover is opened up. Finally, average sediment export from cutlivated areas was higher than most natural land cover classesd at 4.27 t/ha/year.

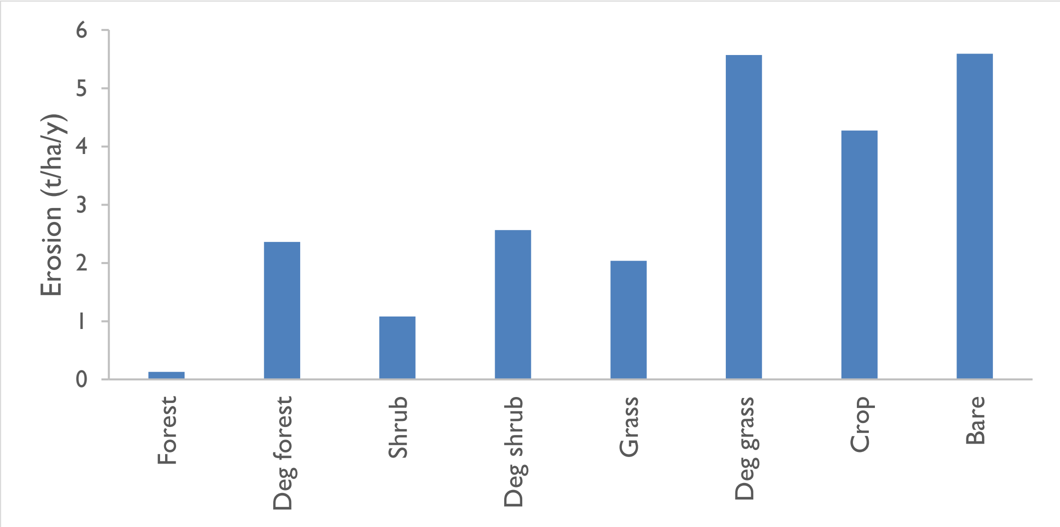


Figure 5-30: Average erosion rates per land cover class across the Mwache Dam catchment

OPTIMAL LOCATION AND EXTENT OF INTERVENTIONS

The Restoration Opportunities Optimization Tool (ROOT) was used to guide the selection of optimal areas for intervention, with the aim of maximising reduction in sediment export to the Mwache Dam while minimising costs. This was used to generate a cost-effective intervention scenario in which interventions are concentrated on areas with the greatest return on investment in terms of sediment reduction. Importantly, this technique could only be used to select optimal areas for *active* interventions *i.e.* interventions which result in a change of land cover conditions (such as restoration of natural habitats or improved erosion control on farmland). Thus, it was not used to select optimal areas for intervention for riparian protection and the establishment of community protected areas, since these interventions are more passive and maintain rather than change current land cover. In the case of riparian protection, we simply assumed protection should be fully carried out in both scenarios. For community conservation, we proposed the focal area under the cost-effective scenario should be a single continuous block of around 20 000 ha in the north of the catchment. This area was selected for its size and proximity to Tsavo East National Park, giving it the best potential for development as a community conservancy.

A key input for the ROOT analysis was an impact potential raster. This provides a spatial map of the potential erosion-reduction benefits of the proposed interventions, based on the difference in sediment export between the current landscape and a hypothetical restored one.

The InVEST SDR model described above was thus adapted to estimate sediment export from a restored landscape, where all the potential conservation interventions were fully carried out. A new land cover was produced for the fully restored landscape, based on the changes that would occur with implementation of the proposed interventions. This included the restoration of degraded natural habitats and the implementation of sustainable land management practices on cropland. The latter required the C and P factors for cropland to be adapted to account for widespread adoption of sustainable land management practices, depending on the particular practices carried out. To achieve this, current cropland areas where split into multiple land cover classes, depending on the particular intervention proposed. Different C and P factors could then be assigned to each cropland class accordingly (Table 5-9), drawing on literature estimates (Thomas, 1997; Hessel & Tenge, 2008; Tenge *et al.*, 2011; Wickama *et al.*, 2014; Panagos *et al.*, 2015b).

Table 5-9. Adjusted Cover Management (C) and Support Practice (P) factors for cropland following implementation of proposed SLM interventions.

Cropland type	Cover Management (C) Factor	Support Practice (P) Factor
Cropland with no SEC measures	0.346	0.79
Cropland flat areas (SEC1)	0.268	0.79
Cropland gentle-moderate slopes (SEC2)	0.268	0.45
Cropland steep slopes (SEC3)	0.268	0.20

Using current land cover with inclusion of the dam, the Invest SDR model estimated sediment export to watercourses across the catchment as a whole to be 683 000 t/year, while sediment export from a full restoration scenario where all proposed interventions are carried out to their maximum extent would decline to 516 000 t/year. This 167 000 t reduction represents a 25% decline in sediment export relative to the current landscape and is the maximum potential sediment reduction achievable through the proposed interventions. To generate the impact potential raster for ROOT, the difference in sediment export between the current landscape (with dam) and fully restored landscape was calculated at the pixel level by subtracting sediment export in the fully restored landscape from sediment export in the current landscape (Figure 5-31).

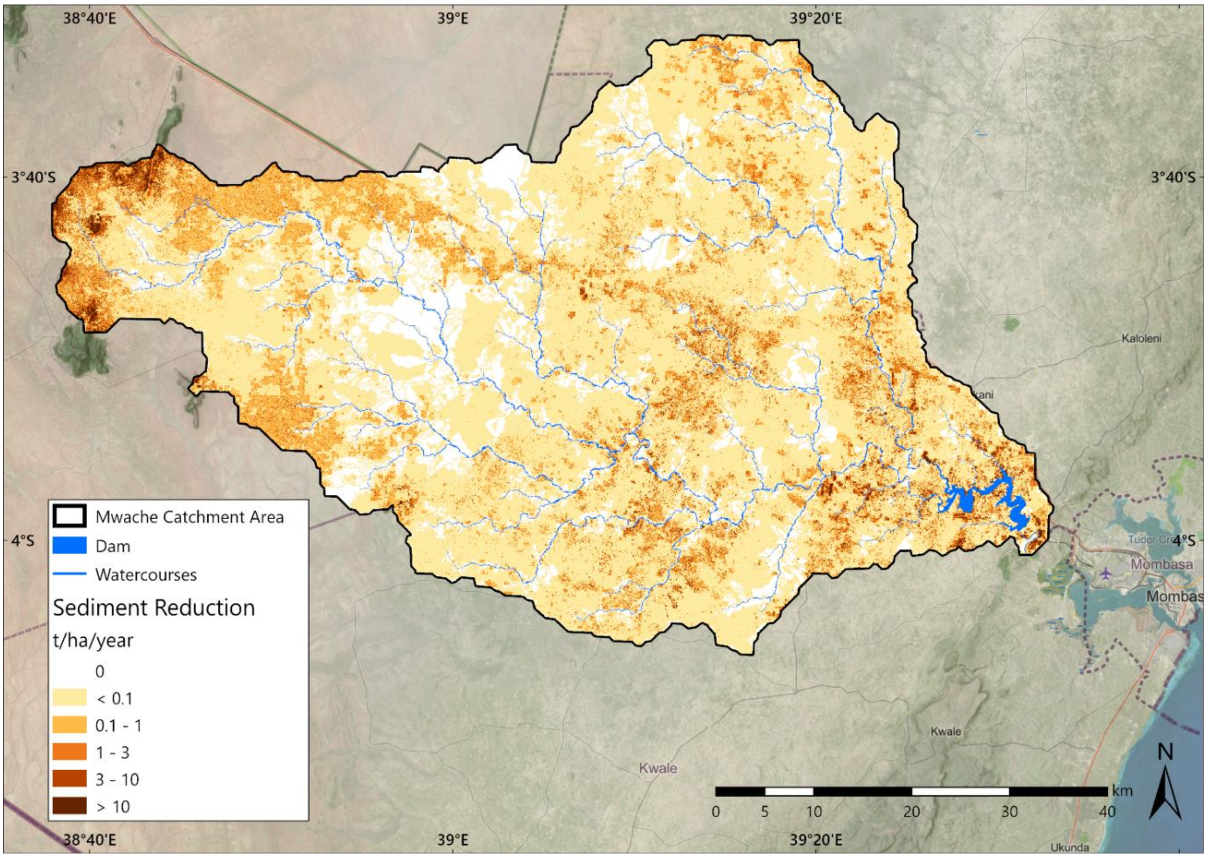


Figure 5-31. Difference in sediment export between the current landscape and a restored landscape where potential interventions are implemented to their full extent

According to the InVEST SDR model findings, notable opportunities for large reductions in sediment export exist at the bottom of the catchment near the dam site, as well as in the far western reaches of the catchment. Steep terrain in these areas results in high potential erosion, particularly where natural land cover has been degraded or converted to agriculture. Thus, implementing conservation interventions on cropland and degraded natural habitats can significantly reduce erosion. High sediment reduction with conservation interventions was also predicted over parts of the central and southern areas of the catchment. This is mostly associated with cultivated areas where implementing the proposed conservation measures could result in a substantial reduction in erosion, particularly on steeper slopes. Other areas where notable sediment reduction opportunities exist are associated with natural land cover which has been degraded and denuded by overgrazing.

While ROOT required pixel-level estimates of costs and sediment export, these estimates are aggregated into a grid of spatial decision units (SDUs) in the pre-processing step of the model. Given the size of the catchment, we selected a hexagonal grid of 100 ha as a feasible target area for planning interventions. During the optimisation runs, ROOT then selects SDUs based on the assumption that all planned interventions are carried out in a particular SDU. In addition to the avoided sediment export in the fully restored landscape, ROOT required a raster of intervention costs. These were obtained from various literature sources, drawing on studies conducted in Kenya as far as possible. All prices were converted to the equivalent 2020 US$ cost and expressed in net present value (NPV) terms. To calculate NPV costs, we assumed a project duration of 25 years and a social discount rate for Kenya of 6.52%. The NPV cost of each intervention included both establishment and maintenance costs for the 25-year time period. The objective set for the ROOT optimisation analysis were to maximise sediment reduction while minimising cost. Details of the inputs used for the ROOT analysis are summarised in Table 5-10.

Table 5-10. ROOT inputs and corresponding details used in selecting optimal sites for conservation intevntions to reduce sedimentation

ROOT input categories	Details of data source used
Impact potential map (marginal values of ecosystem services resulting from restoration	Difference in sediment export (t/pixel/year) between the current landscape and a fully restored landscape where potential interventions are carried out to their maximum extent.
Composite factors	Avoided sediment export weighted by inverse of distance from the planned dam site.
Activity mask	The full extent of potential conservation interventions.
Objective	Maximise sediment reduction while minimising cost

The ROOT optimisation runs produced a range of individual solutions to the trade-off between intervention cost and sediment reduction returns. The trade-off curve between intervention cost and annual sediment reduction is shown in Figure 5-32. Each point on the trade-off curve represents a different optimisation solution produced by ROOT.

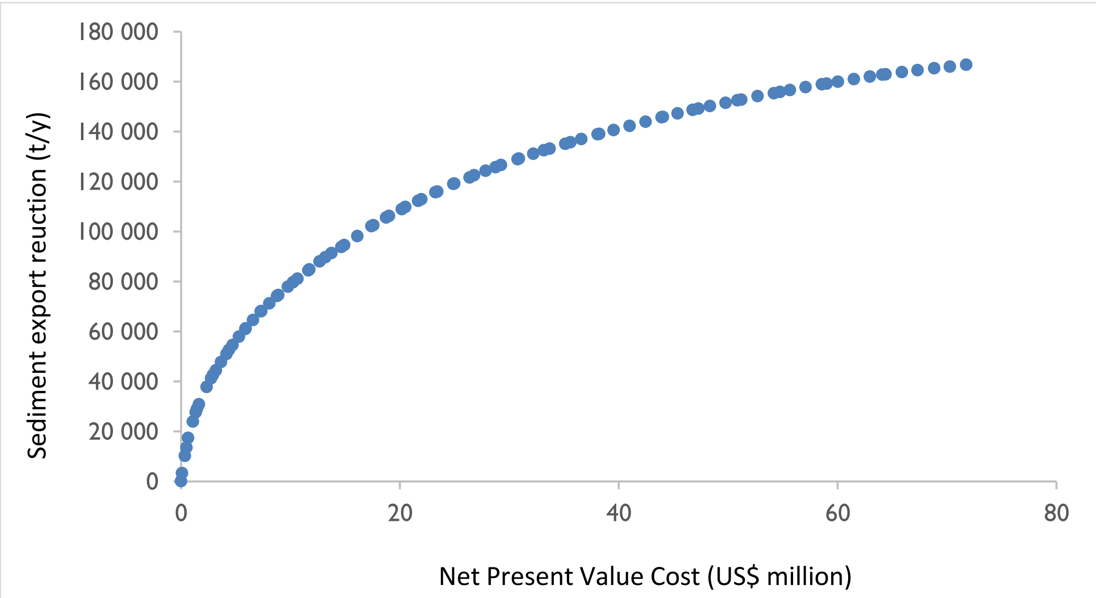


Figure 5-32. Modelled reduction in sediment exported from the land into the river system for different levels of investment in conservation interventions. Derived from 100 optimisation solutions in ROOT.

The trade-off curve allow for selection of a particular optimisation solution based on a balance of cost and sediment reduction considerations. For the scenario analysis, the intention is to select scenarios corresponding to different levels of conservation intervention. Based on the trade-off curve, an optimisation solution with a NPV cost of around US$20 million was selected as an intermediate level of intervention. Though only 28% of the cost of fully carrying out all proposed interventions, it yields a sizeable sediment reduction benefit of 109 000 t/year. This represents a 16% reduction in sediment export relative to current levels, or 65% of the maximum potential sediment reduction that could be achieved if proposed interventions are carried out to their maximum extent.

The selected priority areas for intervention are shown in Figure 5-33. The map suggests the lower eastern and southern central regions of the catchment should be the main areas of focus for interventions. Generally, natural vegetation has been quite extensively degraded and converted to cultivation in these portions of the catchment. Furthermore, terrain tends to be more sloping here, particularly in the lower eastern reaches. Due to these factors, rehabilitating natural vegetation and implementing soil erosion control on farmland has high potential to reduce sedimentation in this part of the catchment. In contrast, few areas were selected for intervention over much of the western part of the catchment, where generally flatter terrain and more intact natural vegetation cover mean there is less potential to reduce erosion through conservation interventions. However, an exception was the far western reaches of the catchment, where substantial areas were selected for intervention under the cost-effective scenario. As with the areas lower down in the catchment, these uppermost reaches are characterized by hilly terrain and higher conversion of natural habitats, resulting in greater potential for proposed interventions to reduce erosion. Finally, the focal area for establishing new conservation areas under the cost-effective scenario is located in the north of the catchment. As mentioned already, this area was chosen based on the relatively large and contiguous areas of natural vegetation remaining and its proximity to Tsavo East National Park.

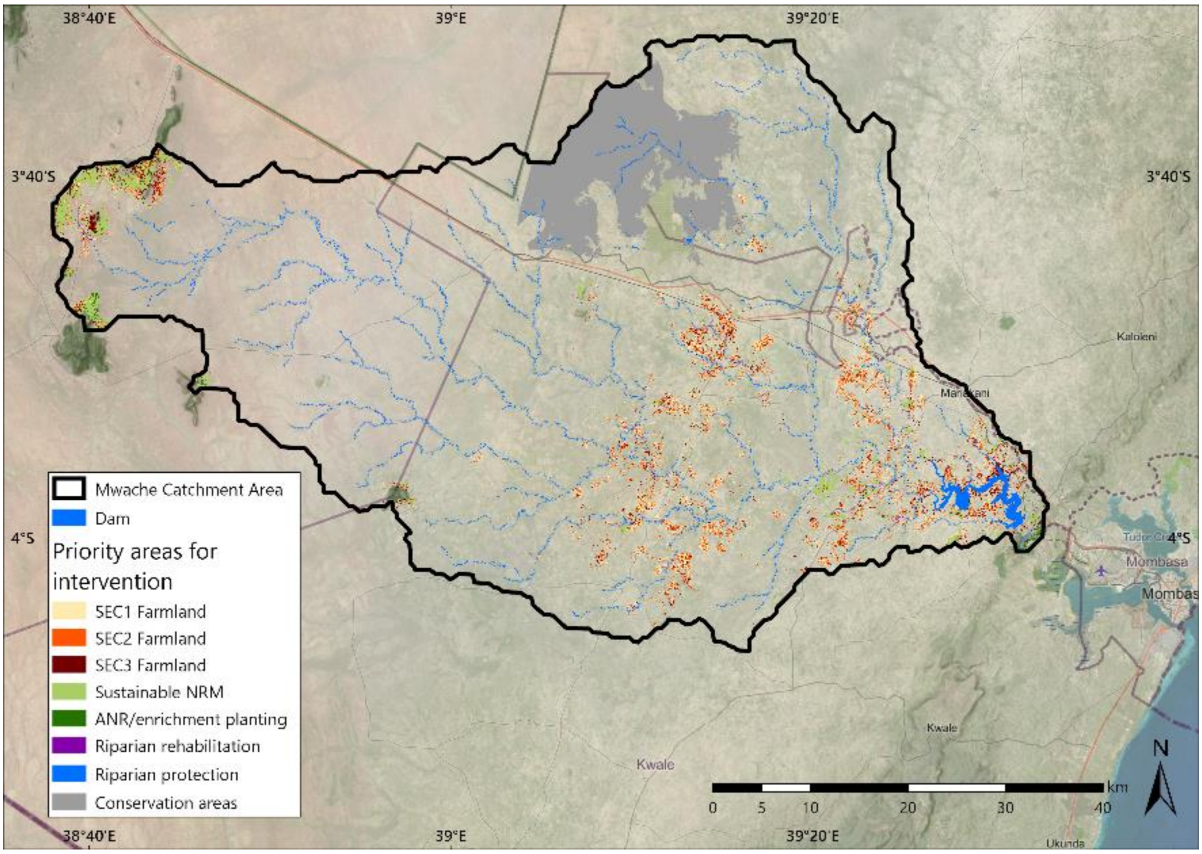


Figure 5-33: Identified priority areas for intervention

SUMMARY OF INTERVENTION PORTFOLIO

SEDIMENT RETENTION

The priority areas for intervention result in a sizeable reduction in the total area and cost of interventions, while still achieving 65% of the total potential sediment reduction benefit. The total establishment cost of interventions is US$6.2 million (Table 5-11). Ongoing costs were estimated to be US$2.2 million per year. The costs of proposed interventions are expressed in present value terms in Table 5-12. The present value cost of priority interventions was estimated to be US$32.9 million. This portfolio of interventions will need to be combined in a package, because some interventions will be more popular than others. This is discussed in Part V.

Table 5-11: Total extent and costs of implementing proposed interventions

Intervention	Extent (ha)	Establishment / setup cost (US$)	Ongoing cost (US$/y)
SEC1 on cultivated land	4 803	715 100	191 000
SEC2 on cultivated land	4 748	1 182 000	307 000
SEC3 on cultivated land	2 893	1 444 000	231 000
Sustainable resource management	4 406	2 131 000	319 000
Active rehabilitation (non-riparian areas)	384	383 000	57 000
Riparian rehabilitation	5 944	260 000	39 000
Riparian protection	201	9 000	253 000
Community conservation areas	19 881	30 000	845 000
Total costs		6 153 000	2 242 000

Table 5-12: Summary table of the extent and costs (in present value terms, US$ millions) of proposed conservation interventions

Intervention	Extent (ha)	PV Cost US$ millions
SEC1 on cultivated land	4 803	2.97
SEC2 on cultivated land	4 748	4.82
SEC3 on cultivated land	2 893	4.16
Sustainable resource management	4 406	5.86
Active rehabilitation (non-riparian areas)	384	1.05
Riparian protection	5 944	3.06
Riparian rehabilitation	201	0.72
Community conservation areas	19 881	10.25
Total costs		32.89

6 PROPOSED INTERVENTIONS IN THE MZIMA SPRINGS RECHARGE AREA

OVERVIEW

This section provides a brief summary of the work of White et al. (GNIplus, 2021a) who undertook a detailed study of the Mzima springs, the potential impacts of conservation interventions, and a suggested payments for ecosystem services model. These results were used in the overall hydrological and economic assessments.

CHARACTERISTICS OF MZIMA SPRINGS RECHARGE AREA

This section provides a summary of the biophysical and socio-economic characteristics of the Mzima Springs Recharge Area, based on a more detailed report from the recently-completed study of that area.

The Mzima Springs is fed by water from the so-called Chyulu Hills Volcanic Aquifer. The Chyulu Hills are formed from volcanic cones that emanate from an elongated vent structure which runs in a north west – south east direction. This mountain range recharges the aquifer. The recharge area is estimated to be around 2,126 km^2 (Atkins, 2018). Field-studies done by Atkins (2018) have confirmed earlier studies that found that the vast majority of the water that flows out of this aquifer, drains to Mzima springs. In other words, it can be assumed that the recharge area of the aquifer is basically the same as the recharge area for the Mzima Springs. The exact flow paths are not know though as this would require detailed monitoring and modelling studies. However, although a smaller part of the aquifer recharge area will not directly drain to Mzima Springs, changes in those areas would likely indirectly affect Mzima Springs, given the fact that also other smaller springs are connected through one single aquifer. In short: the area of influence for the Mzima Springs can be assumed to be the full recharge area of the aquifer.

The alluvial aquifer stretches 100 km across Makueni County and a small part of the recharge area also extends into the counties of Kajiado and Taita-Taveta (Rural Focus Ltd, 2020). The Chyulu Hills National Park covers the eastern portion of the hills covering 741 km^2. This adjoins the Tsavo West National Park to the southwest. The cloud forests of Chyulu Hills play a vital role in capturing rainfall and condensation (from mist) that then infiltrates into the underground aquifer. This water flows southeast to where most of the water emerges at the Mzima Springs, a series of natural springs situated within the Tsavo West National Park some 30 km away from the Chyulu Hills (Figure 6-1). Downstream of the large pools the outflow from the spring joins the Mzima River, a tributary of the Tsavo River, which flows into the Galana River (Wildlife Works Carbon, 2016).

The recharge area encompasses the Chyulu Hills and the lower plains to the northwest. Elevation ranges from 900 m above sea level to a maximum of 2,175 m above sea level at the peak of the Chyulu Hills (Wildlife Works Carbon, 2016). There is significant inter-year variation in the amount and timing of rainfall across the recharge area, varying from an average of 350 mm per annum in the lowland areas to 700 mm in the mountainous Chyulu Hills. Temperatures range from highs of 35 °C in February to lows of 20 °C in July (Wildlife Works Carbon, 2016).

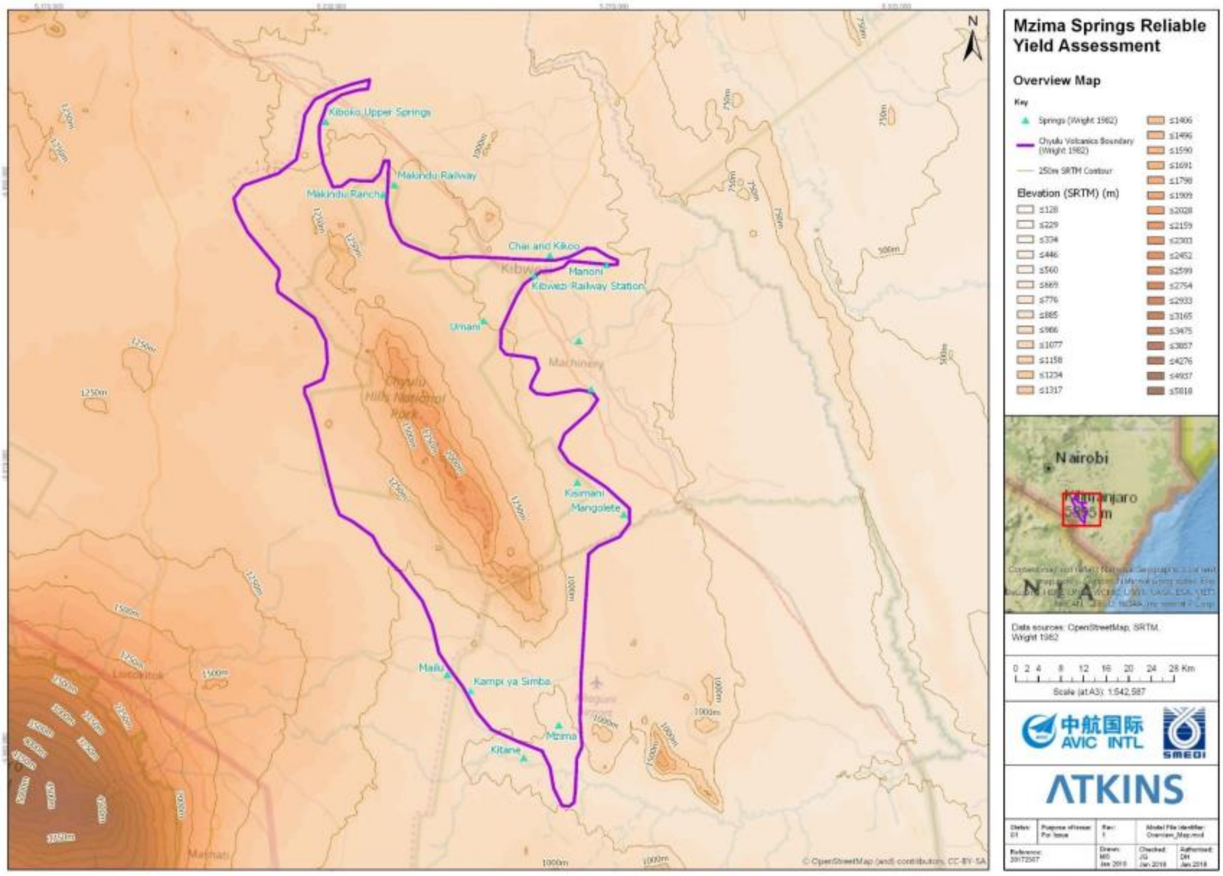


Figure 6-1. Location of the Mzima Springs Recharge Area. Source: Atkins 2018.

Figure 6-2. The Mzima Springs situated in Tsavo West National Park. Source: Emily Le Cornu, AECOM; Luděk Fürst, GoogleEarth

Across the lowland areas of the recharge area, savanna grassland and *Acacia-Commiphora* deciduous bushland are the dominant vegetation types. The volcanic mountainous area of Chyulu Hills is covered in lava forest and a dense, moist cloud forest.

Population densities are higher here than in the Mwache Dam catchment, ranging from 21 people per km^2 on the western side of the recharge area in Kajiado county to upwards of 70 people per km^2 on the eastern side in Makueni County (Wildlife Works Carbon, 2016).

Pastoralism is the dominant livelihood activity undertaken by the Maasai in the western areas of the recharge area. Agro-ecological conditions are more suitable for agriculture in the eastern parts where crop production is the main source of household income. The main cultivated crops are maize, beans and peas. Tourism and trade activities are also important in the eastern parts, mostly along the Nairobi-Mombasa highway. Charcoal and beekeeping activities also contribute to household incomes. However, deforestation, fires, and charcoal production are threatening the health of the Chyulu Hills recharge area.

POTENTIAL LOSS OF OUTPUT DUE TO CATCHMENT DEGRADATION

The Chyulu Hill's forests are threatened by increasing levels of deforestation. Charcoal production, illegal timber harvesting, overgrazing and slash and burn activities to clear and convert forests into agricultural land have all contributed to the decline in forests across the Mzima Springs Recharge Area (see GNIplus, 2021a). The loss in forest cover could lead to a significant decline in rainwater infiltration rates which could have an impact on the groundwater level in the Chyulu Hills catchment, ultimately leading to an overall reduction in the amount of water that is discharged into the Mzima Springs (GNIplus, 2021a). As the population continues to grow, the demand for natural resources increases further exacerbating deforestation across the study area.

PROPOSED PES FOR COMMUNITY FOREST MANAGEMENT

In the case of the Mzima Springs recharge area, the focus of nature-based solutions should be on reducing deforestation and rangeland degradation in the Chyulu Hills, thereby seeking to avoid future declines in recharge capacity and the amount of water that can be extracted from the Mzima Springs.

Efforts have already been made to address forest and rangeland degradation problems in the recharge area through the establishment of a REDD+ Project by the Chyulu Hills Conservation Trust[24] in 2013, further investment is needed to ensure water security. While the project has already generated $12 million from the sale of carbon credits, and is expected to generate another $30 million in its next phase (Chris White, pers. comm.), financial analysis suggests that further income streams are needed to achieve the level of conservation required (GNIplus, 2021). The addition of payments for hydrological services to the revenue stream (which also includes ecotourism, philanthropy and government support) would help to achieve this, as well as helping to smooth funding flows.

The MWF could contribute to the successful protection of the geohydrological functioning of the recharge area through transfers to the Chyulu Hills Conservation Trust. The Project Area covers about 4100 km^2, of which the Chyulu Hills Water Tower[25] makes up a quarter. This would help the Trust to provide a steadier flow of payments and support to communities in return for conservation action. Based on GNIplus (2021), additional funding of US$6.3 million per year is needed to cover the costs of the scheme.

---

24 Nine stakeholder partners make up the Chyulu Hills Conservation Trust. Six of the partners have title to all the land in the REDD+ project area. This is made up of Chyulu Hills National Park and a section of Tsavo West National Park, gazetted to KWS; the Kibwezi Forest Reserve titled to KFS; and four communally owned Maasai Group Ranches (Kuku, Kuku A, Imbirikani, and Rombo). The other three Trustee partners are the local NGOs: The Sheldrick Wildlife Trust, Maasai Wilderness Conservation Trust, Big Life Foundation.

25 Kenya's main water source areas are called Water Towers. The Chyulu Hills Water Tower encompasses the Chyulu National Park, Tsavo West National Park, Kibwezi Forest Reserve and Mbirikani and Kuku Group Ranches. It, traverses Makueni, Taita Taveta and Kajiado Counties. It covers 110 945 ha, of which about 7 895 ha is protected (Kenya Water Towers Agency, 2020).

PART III. MAKING THE BUSINESS CASE FOR MOMBASA WATER FUND

7 IMPACTS ON WATER SUPPLY (YIELD & QUALITY)

OVERVIEW

The hydrology component focuses on the effects of interventions in the Mwache Dam catchment and the Mzima Springs recharge area on the yields of the Dam and the Mombasa water supply system as a whole. The study involved developing a hydrological-sediment model of the Mwache Dam catchment area to estimate the effects of the interventions in that catchment on the yield of the planned Mwache Dam (including the two associated sediment check dams), and then combining this with estimates of the effects of upstream interventions on the Mzima springs which were supplied by GNIplus and AECOM (*in litt.*). Unlike for the Mzima Springs area, where the yield is improved by improving groundwater recharge, in the Mwache catchment, the yield is improved by reducing sedimentation of the dam. Thus, sediment modelling was an important aspect of this study. Both the Mwache hydrology and the system yields were modelled using the Water Evaluation and Planning tool (WEAP).

DATA AND METHODS

PREVIOUS STUDIES

Several hydrological assessments have already been done for the Mwache Dam catchment. The hydrology of the Mwache Dam catchment is described in the ***Detailed Design Report on Mwache Multipurpose Dam Development Project*** (CES 2014). The report states that the long term annual average discharge at the Dam site is 112.8 MCM (3.6 m^3/s) from a catchment of 2,250 km^2. The report calculates sediment accumulation to be 40.25 MCM (889 $m^3/km^2/yr$) after 100 years, based on 1.7 MCM/yr of sediment removal from the proposed check dams upstream of Mwache Dam. The report also estimates that if the catchment is treated to reduce sediment yield the design life of the dam can be extended to 160 years. The report presents a business case around the sediment removal stating that the total cost of removing the sediment will be Ksh 476 Million/yr (US$4.29 million/yr) which could be offset by the sale and use of the sediment for building sand and brick making.

The ***Mwache Dam Design Review Report*** (Nippon Koei et al. 2017) provided a revised analysis of the hydrology of the Mwache watershed based on a catchment area of 3,600 km^2. The dam size was calculated from a short flow time series at RGS 3MA03, just upstream of the dam site which was used to calibrate a tank model to simulate rainfall-runoff. Sediment yield was estimated using a SWAT model. Notably, the report estimated a sediment yield of 1.62 MCM/yr (451 $m^3/km^2/yr$). The report estimated a total of 46 MCM of sediment accumulation in Mwache Dam after 100 years, on the basis of 1.09 – 1.34 MCM being removed annually from the upper check dams as shown in Figure 7-1.

In comparison, the ***Mwache Physiographic Report*** (RTI/ICRAF 2017), based also on SWAT modelling, estimated a sediment yield of 4.484 Million tonnes/yr of sediment (1,231 $t/km^2/yr$). Expressed as a volume, this is 3.737 MCM/yr (1026 $t/km^2/yr$). This estimate is 2.3 times greater than that predicted in the Nippon Koei 2017 report.

In this study, sediment yield was also estimated using InVEST, resulting in an estimated average sediment yield of 156 t/km^2/year, which was much lower than the Nippon Koei estimate.

This illustrates the uncertainty regarding the actual sediment yield and the potential risk to Mwache Dam being much greater than indicated in the Nippon Koei report which is the least conservative in terms of estimated sediment yield.

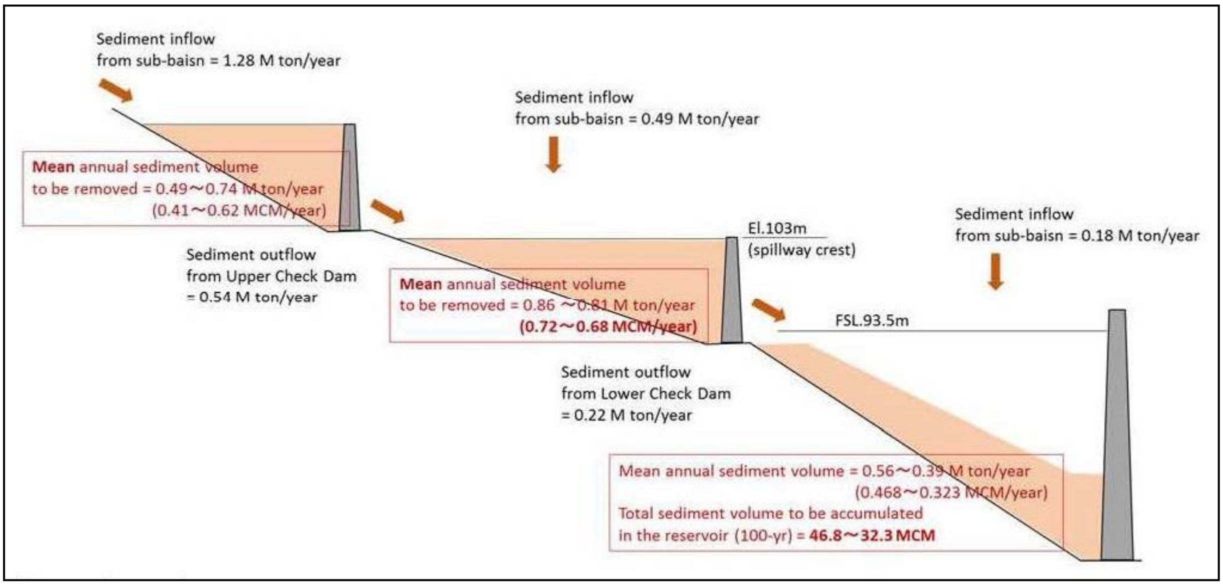


Figure 7-1. Total erosion loadings according to the Dam Design Review Report.

MODELING APPROACH

To assess the impact of possible portfolios of Nature-based Solutions (NbS) on dependent economic and environmental services, a hydrological modelling tool is required that allows assessing the effectiveness of a number of scenarios. Often, Water Fund business case studies have a focus on the hydrological response of NbS. In that case, a physically based model tool like SWAT is typically preferred. However, this study required an estimate of system yield, which required modelling overall yield from interconnected water infrastructure. In summary, requirements for the tool to be selected were:

- Modelling hydrological response to different land-covers and land-uses;
- Source production and routing of sediments and other water quality constituents;
- Simulation of impacts of sedimentation on reservoir water storage capacity;
- Modelling water quality;
- Flexible in selecting simplified modelling approaches versus more physically based approaches (e.g. soil moisture modelling);
- Flexible integration of modelling outputs from other platforms;
- Focused on scenario analysis;
- Flexible in data scarce environments and automatic links with global climate and remote sensing-based land-cover datasets;
- Availability of training material and previous experiences in Kenya;
- Freely available for users in Kenya; and
- Large user-base and forum.

A tool increasingly used for water resources and Integrated Water Resources Management (IWRM) assessments is WEAP (Water Evaluation and Planning tool) developed by the Stockholm Environment Institute (SEI). WEAP covers the above requirements and operates on the basic principle of a water balance and can be applied to catchment and agricultural systems: either a single watershed or complex transboundary river basin systems. WEAP can simulate a broad range of natural and engineered components of these systems, including rainfall runoff, baseflow, and groundwater recharge from precipitation; sectoral demand analyses; water conservation; water rights and allocation priorities, reservoir operations; hydropower generation; pollution tracking and water quality; vulnerability assessments; and ecosystem requirements.

WEAP represents a particular water system, with its main supply and demand nodes and the links between them, both numerically and graphically. The concept-based representation of WEAP means that different scenarios can be quickly set up and compared, and it can be operated after a brief training period. WEAP is being developed as a standard tool in strategic planning and scenario assessment and has been applied in many regions around the world.

A key feature that that the WEAP model needs to include for this study is the capability to simulate the soil water balance and erosion in a dynamic way. This dynamic component should be two-fold. First, instead of focusing on average conditions the model should include actual variability in daily weather conditions that influence hydrology, erosion, and sedimentation. WEAP has a soil moisture module that can be activated that allows simulating the principal flows in the soil (see Figure 7-2). Second, conditions of today are different from future ones so WEAP should allow scenario analysis to assess how NbS influences hydrological processes including erosion. WEAP has specific features and interface components for scenario analysis. Also, important to note, is that recently the WEAP model was expanded with a module to evaluate erosion and sediment transport in rivers. This erosion plugin uses the same concepts and equations as used in the SWAT model (MUSLE-based).

Box 2. Key features of WEAP

- Integrated Approach: Unique approach for conducting integrated water resources planning assessments.
- Stakeholder Process: Transparent structure facilitates engagement of diverse stakeholders in an open process.
- Water Balance: A database maintains water demand and supply information to drive mass balance model on a link-node architecture.
- Simulation Based: Calculates water demand, supply, runoff, infiltration, crop requirements, flows, and storage; pollution generation, treatment, and discharge; and in-stream water quality under varying hydrologic and policy scenarios.
- Policy Scenarios: Evaluates a full range of water development and management options, and takes into account multiple and competing uses of water systems.
- User-friendly Interface: Graphical drag-and-drop GIS-based interface with flexible model output as maps, charts and tables.
- Model Integration: Dynamic links to other models and software, such as QUAL2K, MODFLOW, MODPATH, PEST, Excel and GAMS. Links to all other models can be developed quite easily since WEAP can read and write plain text files similar to SWAT, SPHY, SWAP, Mike11, HEC-HMS, HEC-RAS and Geo-SFM.
- Inclusion of optional plugins, like for example the WEAP Erosion Plugin

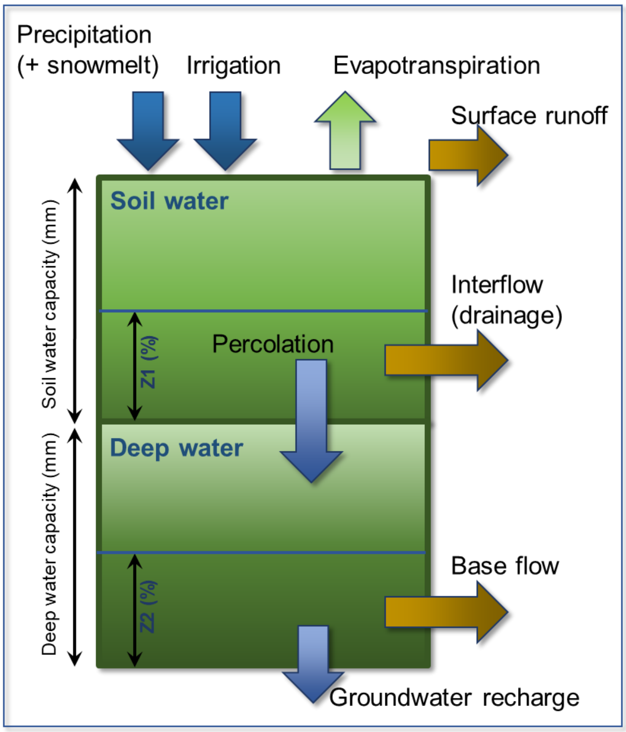


Figure 7-2. Processes included in the WEAP module that are calculated at the calculation unit-level.

Erosion and sediment yield require specific attention in the modelling of the business case. As explained in the main report, two tools are used for modelling erosion and sediment yield: InVEST (using average climate conditions) and WEAP (using dynamic weather conditions). Parameters used for the erosion modeling among both tools are harmonized to the extent possible (for example the landcover-based C-factor).

DATA

Sub-catchments

To ensure that the current study is aligned with previous work in the Mwache Dam catchment, the catchment is divided into the same 21 sub-catchments as presented by the previous Mwache Physiographic Report (2017). A very minor deviation in total catchment area was found (3640 km^2 versus 3571 km^2) caused by a few flat areas on the borders of the catchment. It should be emphasized that small deviations in assessing catchment areas are common as minor changes in outlet point, quality of the DEM and even the georeferencing choice might lead to those differences.

Figure 7-3 shows a map of the resulting catchment delineation. Table 7-1. presents the names and numbering used for this assignment of all sub-catchments. Figure 7-4 shows a screenshot of the sub-catchment delineation in the modeling tool.

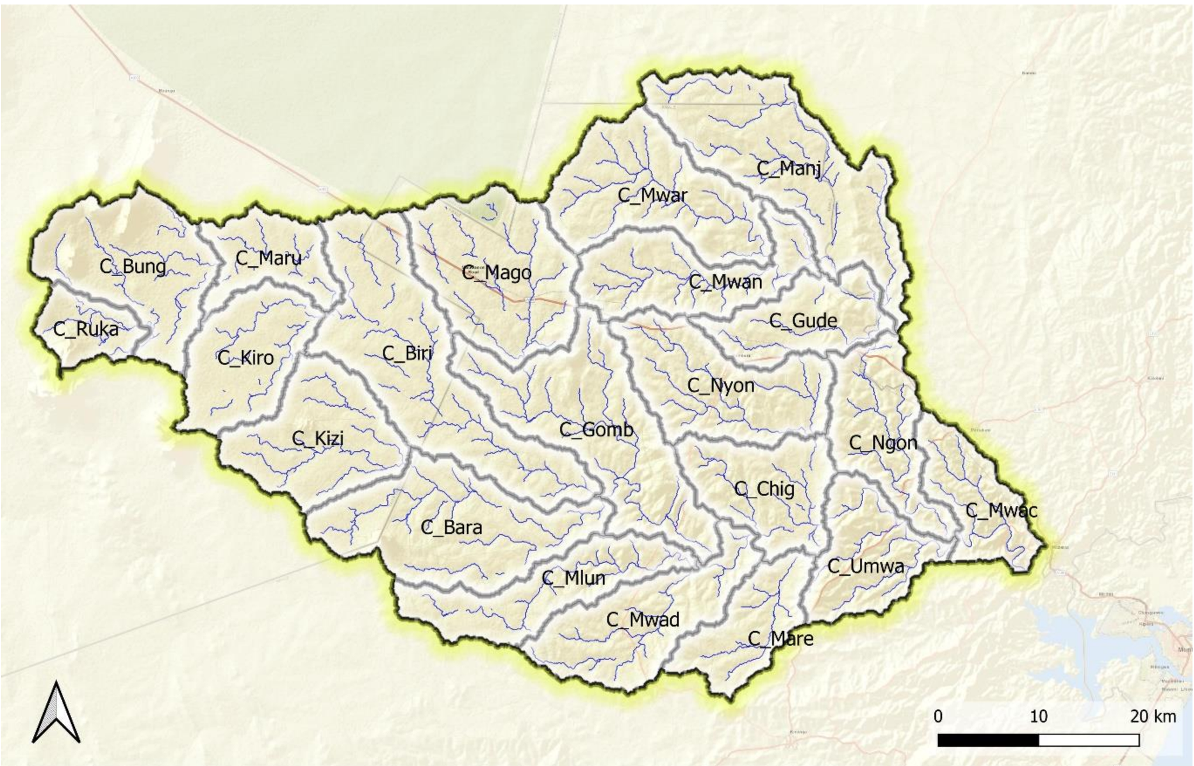


Figure 7-3. The 21 sub-catchments as used in the WEAP model and the four-letter abbreviations.

Table 7-1. Names of the 21 sub-catchments and the abbreviations used in this report.

Sub-catchment	Abbreviation	County	Sub-county
Mwachiga	Mwac	Kwale	Kinango
Upper Mwache	Umwa	Kwale	Kinango
Mwang'ombe Ngoni	Mwan	Kwale	Kinango
Nyongoni	Nyon	Kwale	Kinango
Barani	Bara	Kwale	Kinango
Chigulu Ngeyeni	Chig	Kwale	Kinango
Mwadudua Vigurungani	Mwad	Kwale	Kinango
Gombo Bomani	Gomb	Kwale	Kinango
Mwang'ombe	Ngon	Kwale	Kinango
Mlunguni	Mlun	Kwale	Kinango
Birikani	Biri	Kwale	Kinango
Mwaruphesa Dambale	Mwar	Kwale	Kinango
Gude Dambale	Gude	Kwale	Kinango
Magombe Shariani	Mago	Kwale	Kinango
Marenje Mlunguni	Mare	Kwale	Kinango
Manjewa	Manj	Kwale/Kilifi	Kinango Kaloleni/ Ganze
Marungu	Maru	Kwale	Voi
Bunguta	Bung	Kwale	Voi
Kizima Bomani	Kizi	Kwale	Voi
Rukanga	Ruka	Kwale	Voi
Kirongwe Rukinga	Kiro	Kwale	Voi

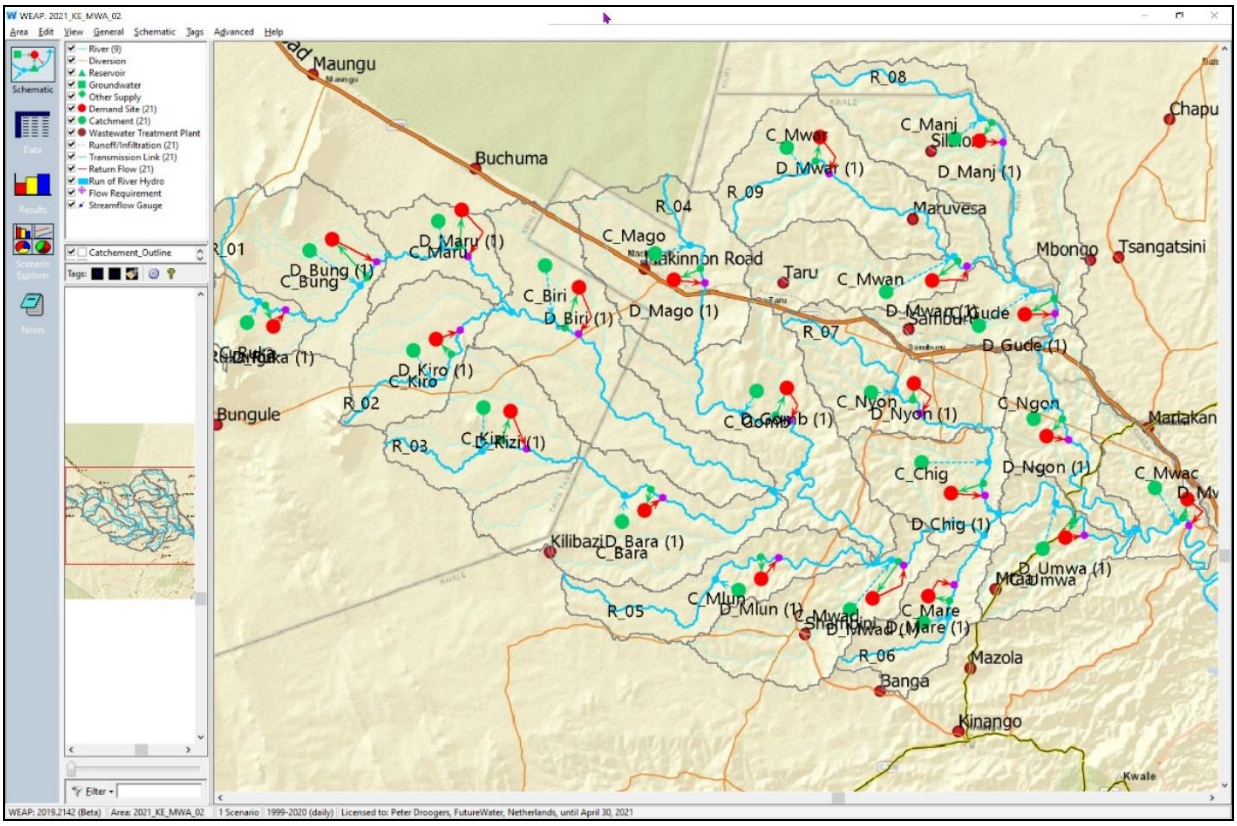


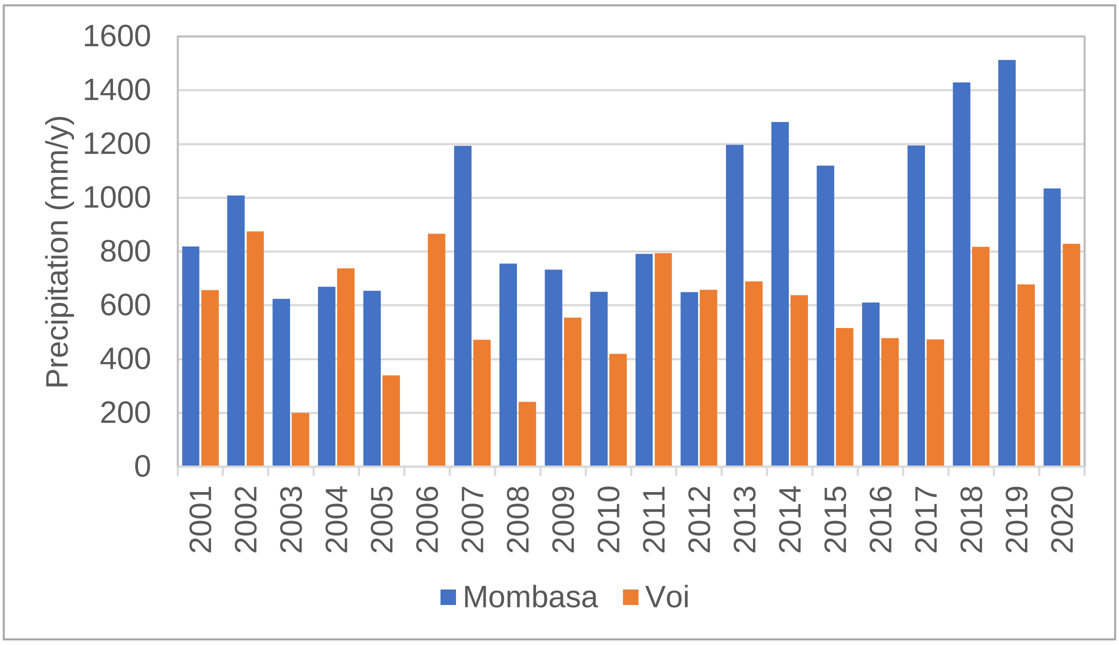
Figure 7-4. Screenshot of the WEAP model showing the overall schematic of the model developed for the Mwache Catchment.

Climate

Climate data used in prior studies were analyzed. The environmental and social impact assessment (ESIA) report of Mwache dam is very generic on rainfall data. It mentions that most of the rainfall in this catchment occurs between March – July and then in October – December with peak rainfall session in May and November. The average rainfall is 500 mm – 1,200 mm per year.

The Detailed Design Report (CES, 2014) had access to monthly rainfall records that were made available from Kenya Meteorological Department for ten rain gauge stations in and around the Mwache Dam catchment. However, those data are very patchy and incomplete (see p. 1-10 of the CES report). Thus, for this study rainfall data was generated using a stochastic rainfall generator.

To mitigate the lack of reliable, gap-filled climate data, it is often preferred to use a hybrid approach, in which both station data is used, as well as data from global rainfall products that are produced from satellite-based and model-based data. This approach is followed also for this catchment. The global meteorological data database that includes data that is validated according to World Meteorological Organization (WMO) standards is the Global Surface Summary of the Day (GSOD) database. The closest two rainfall stations (Mombasa and Voi) to the catchment were obtained, with daily records from 2001 to 2020. The average rainfall for Mombasa is 944 mm y^{-1} and for Voi 638 mm y^{-1}. Annual variation can be substantial as can be observed from Figure 7-5. Monthly precipitation rate follows the well-known trend of two wet seasons.



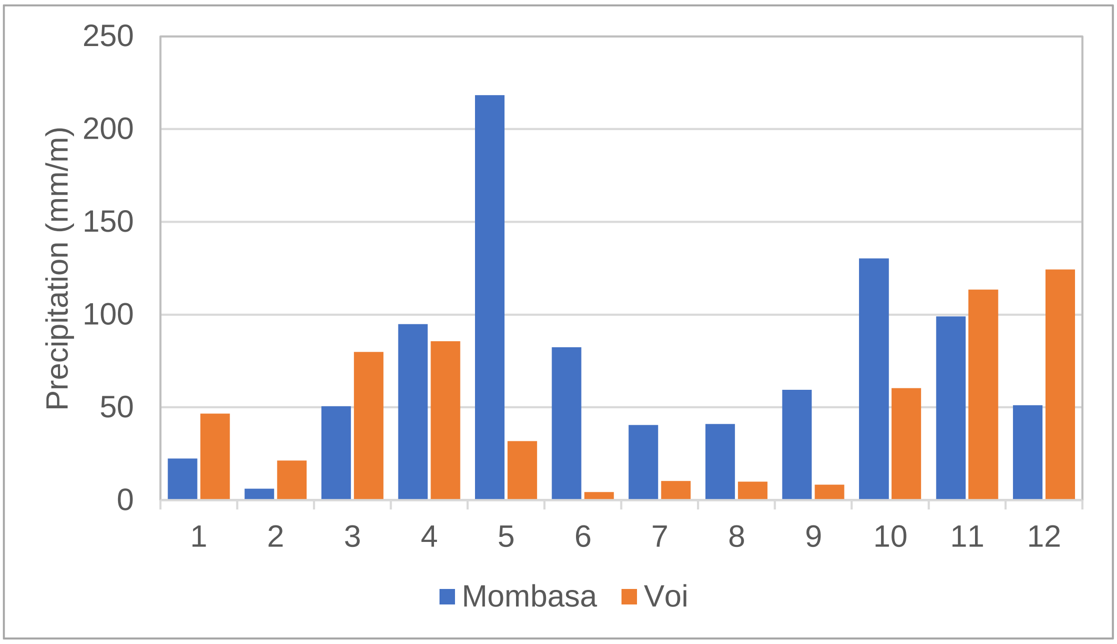


Figure 7-5. Precipitation data from two station obtained from the GSOD database. Top: annual sums; bottom: 20-years monthly averages (2001-2020).

To capture the spatial variability satisfactorily, global reanalysis products are typically preferred. The number of global climate data sets is growing substantially. An interesting overview of available data sets is provided by (Gleixner, Demissie & Diro, 2020). Many of those products are based on so-called reanalysis methods. Reanalysis data are produced by combining climate model estimates with observations via data assimilation, therefore providing optimized global estimates of climate data without spatial or temporal gaps.

The ERA5 reanalysis product is considered as state-of-the art and is often seen as reference to be used. Climate data from the ERA5-Land data set has been obtained for the catchment. It is known that the ERA5 data is consistent with all other climate variables (temperature, wind, dewpoint, etc). A typical example of data that can be obtained is shown in Figure 7-6.

Box 3. ERA5 and ERA5-Land Reanalysis Data

ERA5 is the fifth generation European Centre for Medium-Range Weather Forecasts (ECMWF) reanalysis for the global climate and weather for the past 4 to 7 decades. Currently data is available from 1979. Reanalysis combines observations into globally complete fields using the laws of physics with the method of data assimilation (4D-Var n the case of ERA5). ERA5 provides hourly estimates for a large number of atmospheric, ocean-wave and land-surface quantities.

ERA5-Land is a reanalysis dataset at an enhanced resolution compared to ERA5. ERA5-Land has been produced by replaying the land component of the ECMWF ERA5 climate reanalysis. Reanalysis combines model data with observations from across the world into a globally complete and consistent dataset using the laws of physics. Reanalysis produces data that goes several decades back in time, providing an accurate description of the climate of the past.

Source: ECMWF

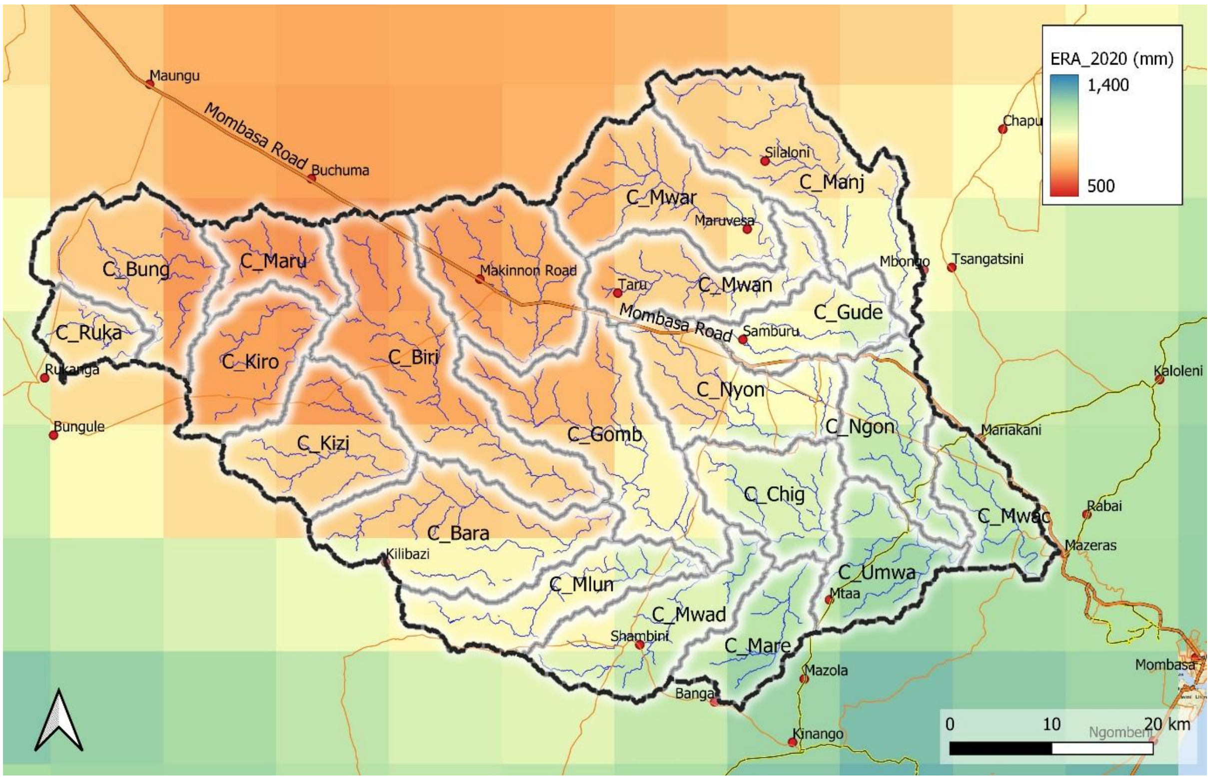


Figure 7-6. Annual precipitation data for 2020 as obtained from the ERA5-Land database.

The ERA5-Land daily data are summarized in the following Figures and Tables. The following conclusions can be drawn:

- Long term annual average precipitation over the entire basin is 630 mm y^{-1}. (1981-2020). Year-to-year variation can be substantial with values between 425 and 885 mm y^{-1} as minimum and maximum, respectively. A clear trend cannot be observed, although the most recent years are somewhat wetter. (Figure 7-7)
- A more long-term trend seems to indicate that the last 10 years are somewhat dryer compared to the last 40 years, by about 5%. (Figure 7-8)
- Spatial variation in precipitation is huge. The eastern (coastal) part of the Mwache Dam catchment receives rainfall up to 800 mm y^{-1} on average, while the wester (inland) parts receive about 400 mm y^{-1}. (Figure 7-9)

- Year-to-year variation within the 21 sub-catchments is also substantial. In some years rainfall can be 50% higher compared to the long-term averages. In dry years in the more western (inland) sub-catchments rainfall can be as low as 300 mm y^{-1}. (Figure 7-9)

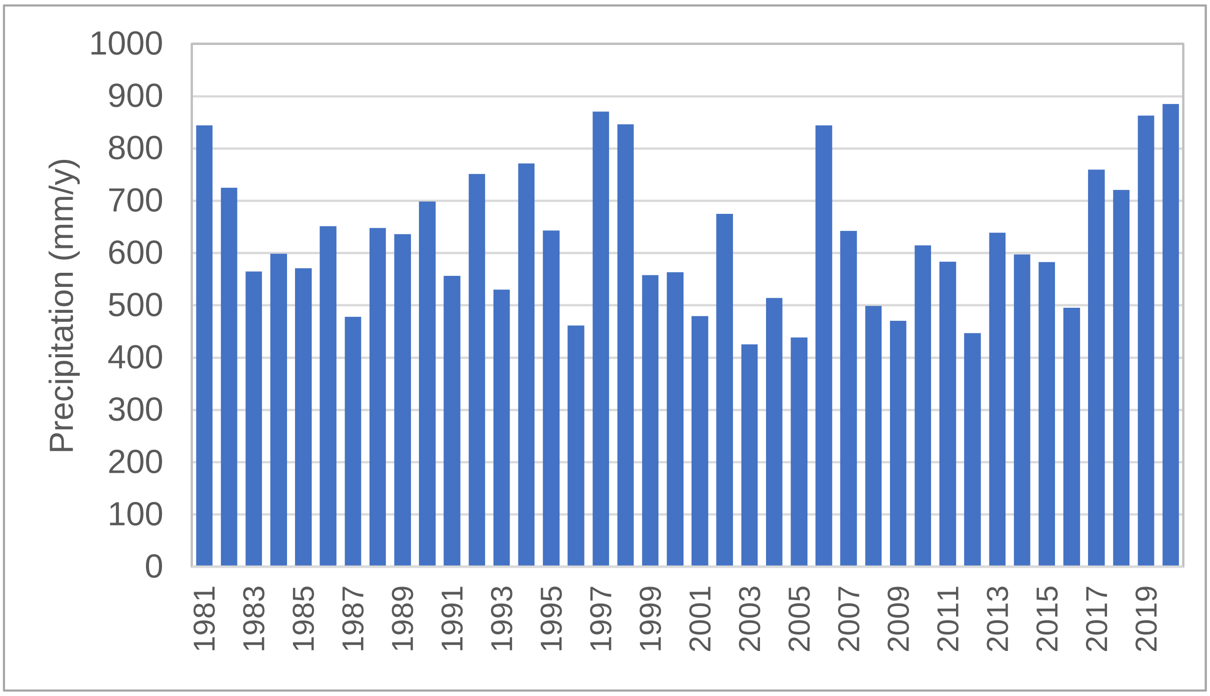


Figure 7-7. Annual average precipitation over the entire Mwache Dam catchment covering a period of 40 years. Source: ERA5-Land.

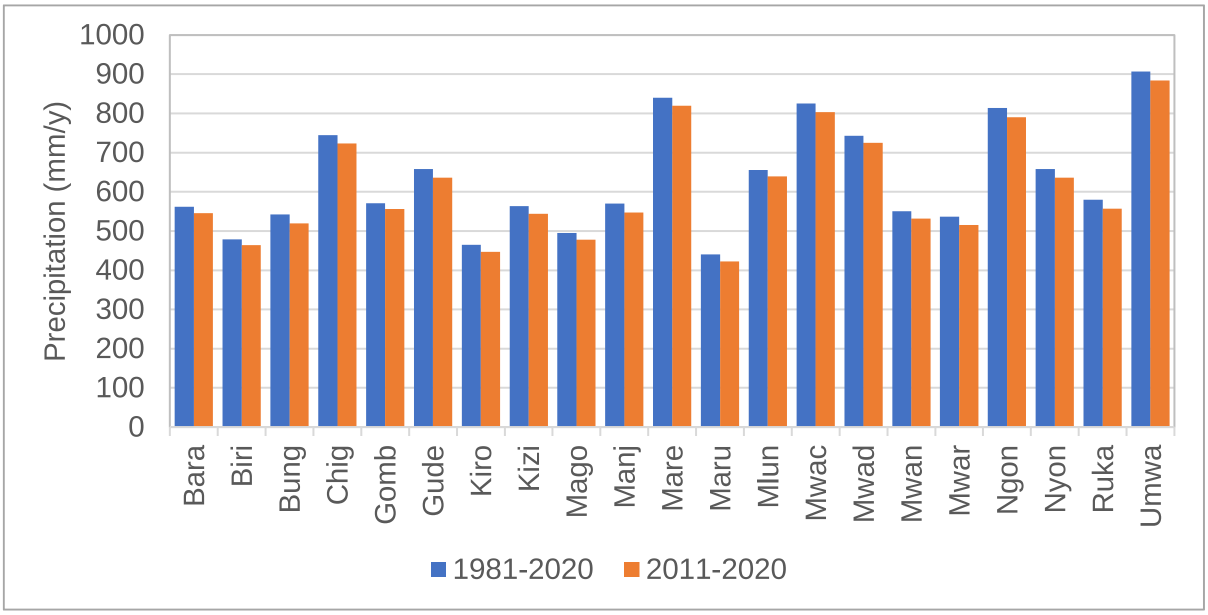


Figure 7-8. Comparing annual average precipitation over the entire Mwache Dam catchment comparing the last 40 years to the last 10 years. Source: ERA5-Land.

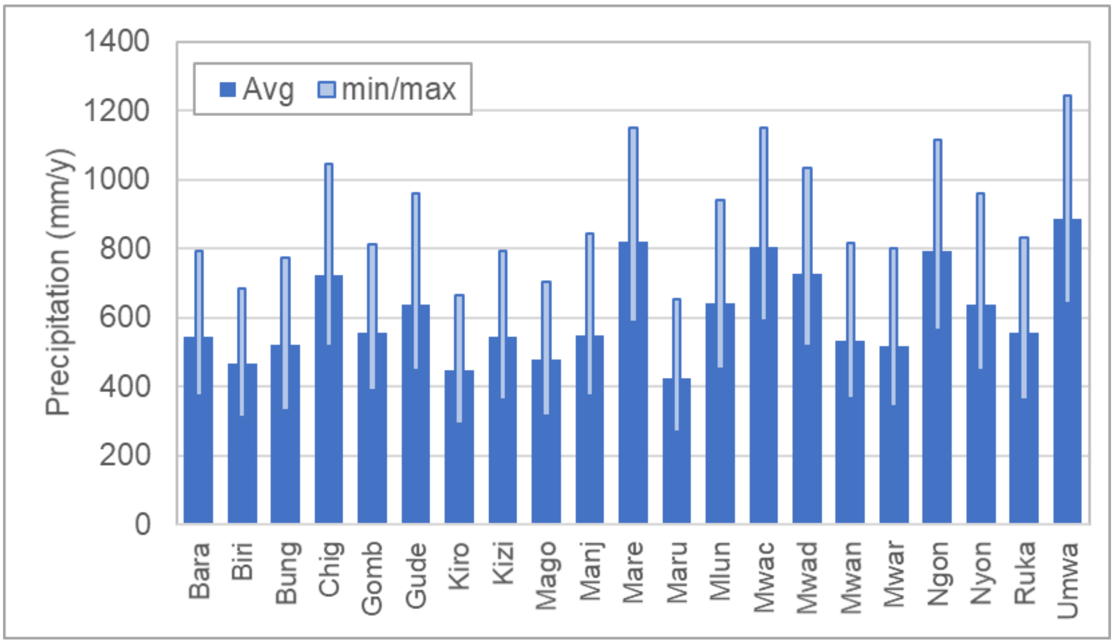


Figure 7-9. Annual average precipitation (and min max) for each of the 21 sub-catchments over the period 2001-2020. Source: ERA5-Land.

Finally, a comparison between the observations of the two GSOD data and the ERA5-Land data has been undertaken. The Mombasa observed rainfall is compared with the nearest sub-catchment (Mwac) and the Voi observation with the Bung sub-catchment.

The Mombasa and nearest sub-catchment (Mwac) data are quite similar and trends in wetter and dryer years are well overlapping. In general, the Mombasa records are somewhat higher compared to the ones from the Mwac sub-catchment. This can be explained by various factors. First of all, point data is compared to data from a larger area so some averaging can cause this deviation. Also the Mombasa station is closer to the coast which receives more rainfall compared to the sub-catchment that is about 25 kilometers further inland.

The comparison between rainfall data from the Voi station and the nearest sub-catchment data from ERA5-Land (Bung) are presented in Figure 7-11. Especially for some of the years in the beginning of this century Voi precipitation records ate very high; in some years even higher than the Mombasa observations. The last 10 years a good comparison between the Voi data and the ones from Bung can be seen. The monthly patterns are also well comparable, with the exception of the month May which can be explained by some unlikely high rainfall events in the beginning of this century.

Other climate data required to run the model were obtained from the following sources:

- Temperature was obtained from the ERA5-Land dataset on a daily base
- Wind speed was considered to be constant at 2 m s^{-1}
- Relative humidity was based on the CES (2014) report

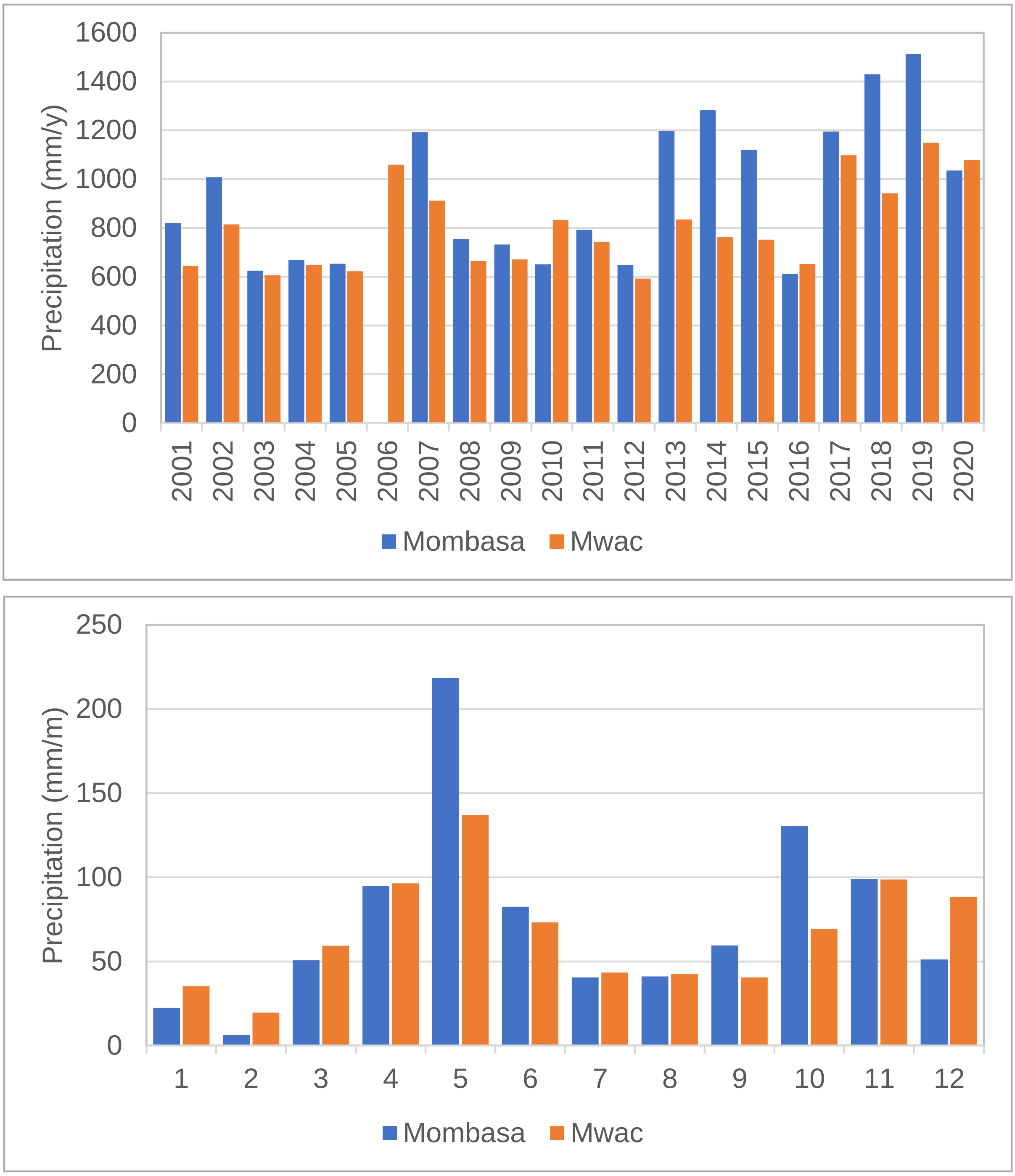
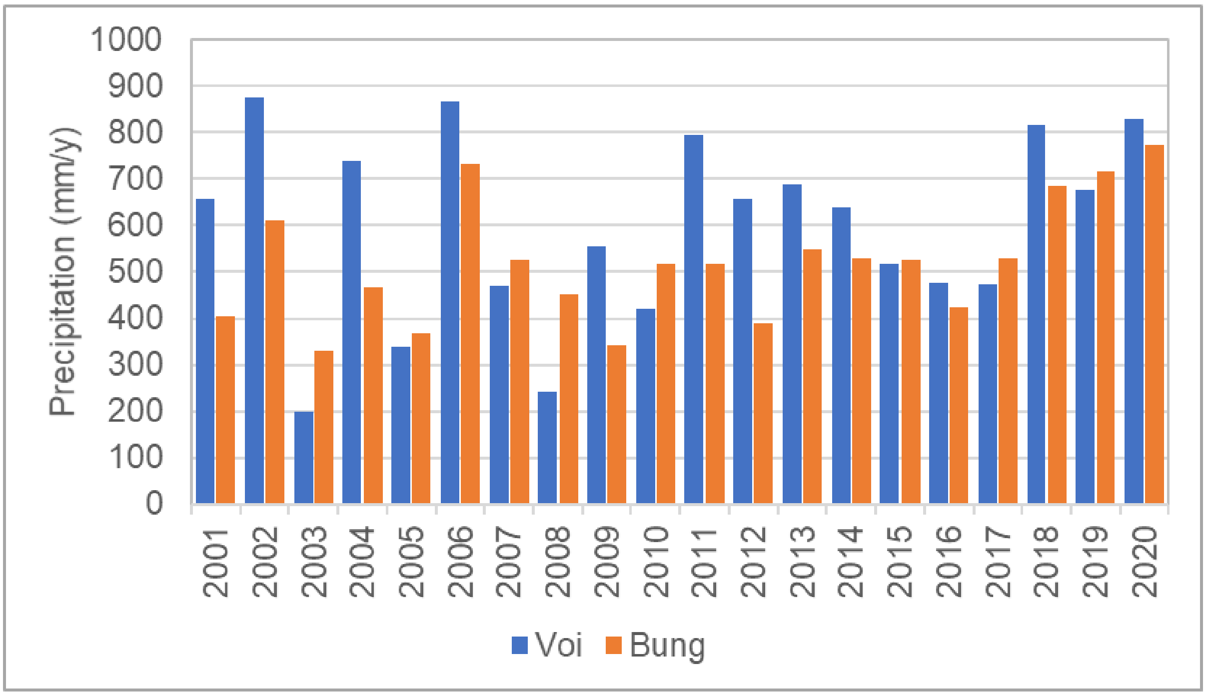


Figure 7-10. Comparison between the observed rainfall data to the reanalysis gridded data for the eastern (coastal) region). Top: annual total, bottom average monthly over 20 years. Source: GSOD and ERA5-Land.



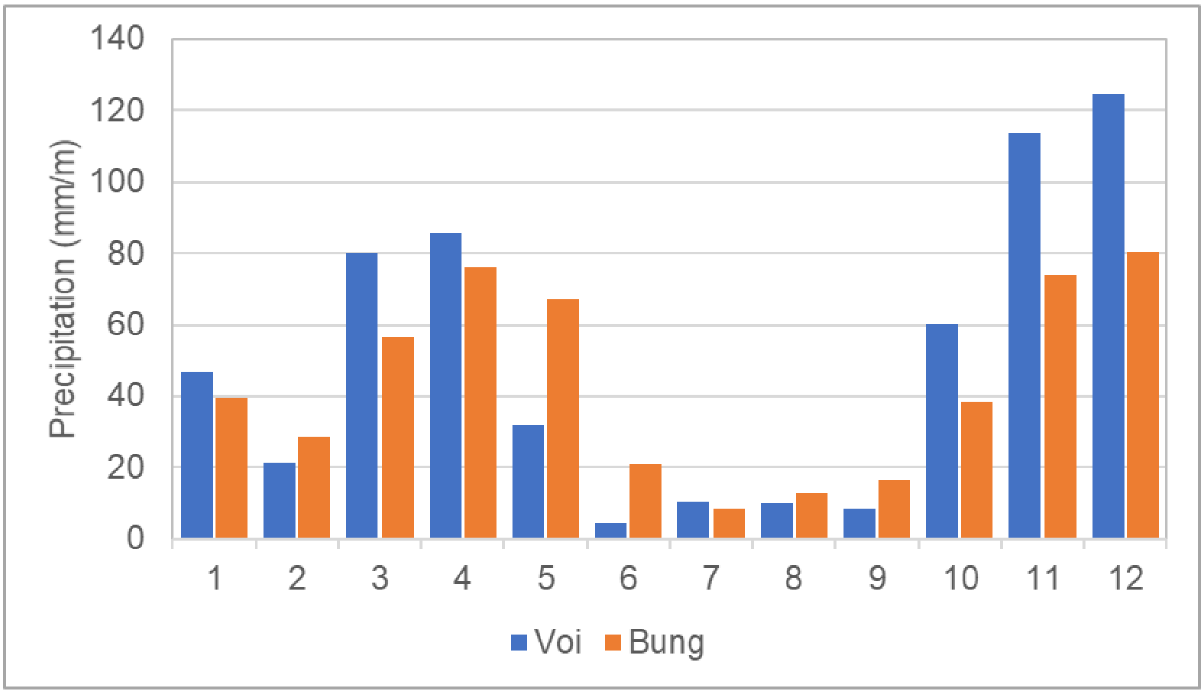


Figure 7-11. Comparison between the observed rainfall data to the reanalysis gridded data for the western (inland) region. Top: annual total, bottom average monthly over 20 years. Source: GSOD and ERA5-Land.

Landcover

Various landcover data are available for the region[26].

- Copernicus Climate Initiative 20 m land cover for 2016, also referred to as Sentinel 2017 (ESA, 2017)
- Globeland; based on Landsat TM5 and ETM+ at resolution 30 m. Presented in Athi Basin Plan[27] Annex A (2020) and Physiographic Survey of Mwache Watershed (2017) http://www.globeland30.org/home_en.html
- 1981–1994 AVHRR-derived LU/LC and
- 2001 and 2013 MODIS-derived data sources as previously mentioned.

In the context of the Mombasa Water Fund an updated landcover maps has been produced, based on the Copernicus 2016 20m LC dataset, merged with the Trends.Earth degradation data. Details are presented in the previous Chapter. This updated land cover data has been used for the WEAP model.

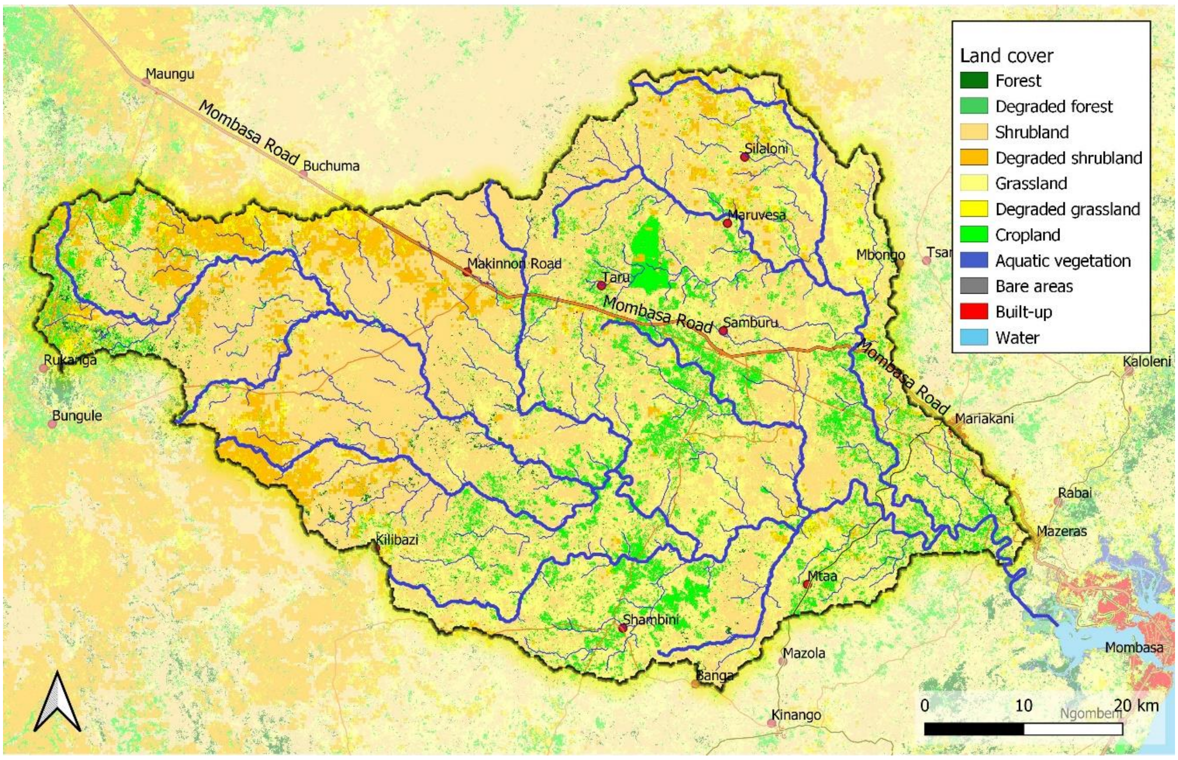


Figure 7-12. Land cover of the Mwache Dam catchment.

[26] Full overview in: Physiographic Survey of Mwache Watershed, 2017

[27] Note that in the full report also the ESA 2017 was presented

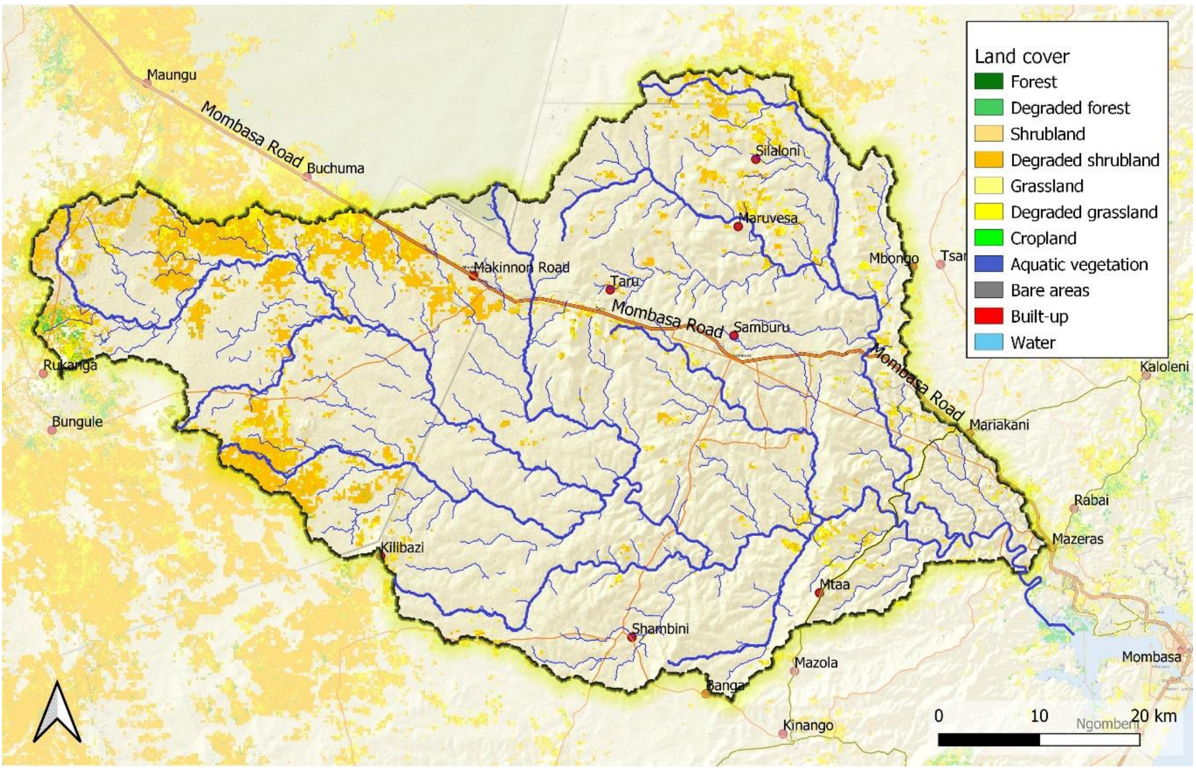


Figure 7-13. Degraded land covers in and around the Mwache Dam catchment. Same as previous figure, but only degraded lands are shown.

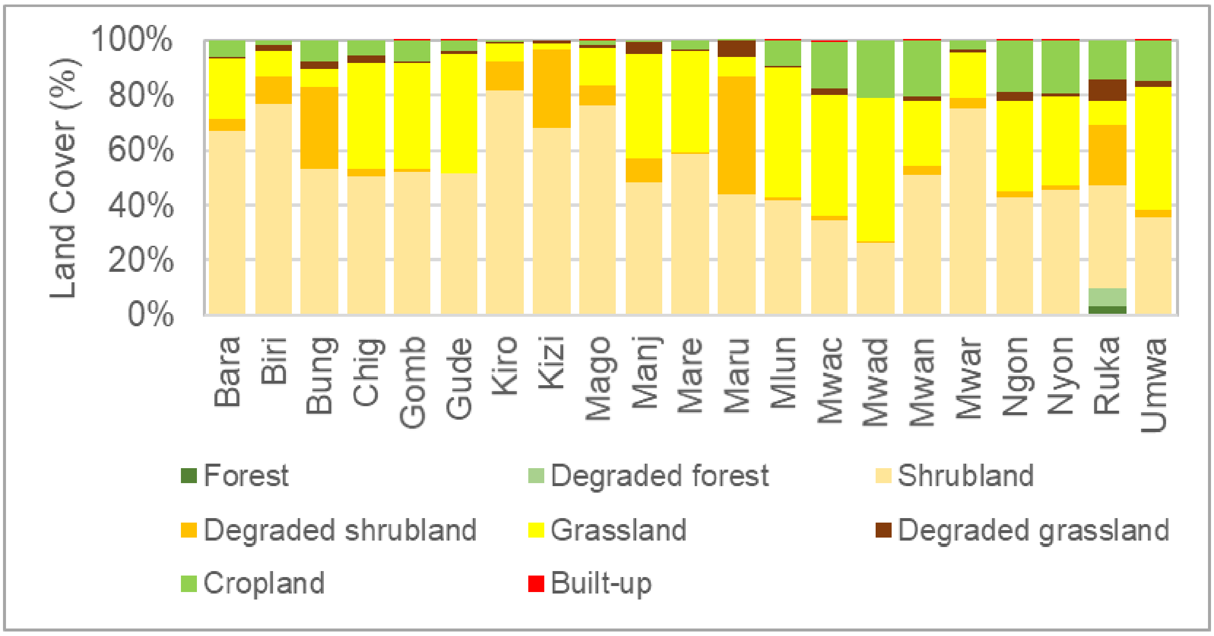


Figure 7-14. Distribution of land cover types across the sub-catchments.

Elevation and slopes

Elevation and slope data are important inputs as those drive the hydrological processes. Especially the distribution of runoff between fast (=surface) and slow is relevant to the amount of erosion that will be generated. The Digital Elevation Model (DEM) used in this study is the

HydroSHEDS which is based on the SRTM[28]. Hydrological data and maps based on SHuttle Elevation Derivatives at multiple Scales

HydroSHEDS is a mapping product that provides hydrographic information for regional and global-scale applications in a consistent format. It offers a suite of geo-referenced data sets (vector & raster) at various scales, including river networks, watershed boundaries, drainage directions, and flow accumulations. HydroSHEDS is based on high-resolution elevation data obtained during a Space Shuttle flight for NASA's Shuttle Radar Topography Mission (SRTM).

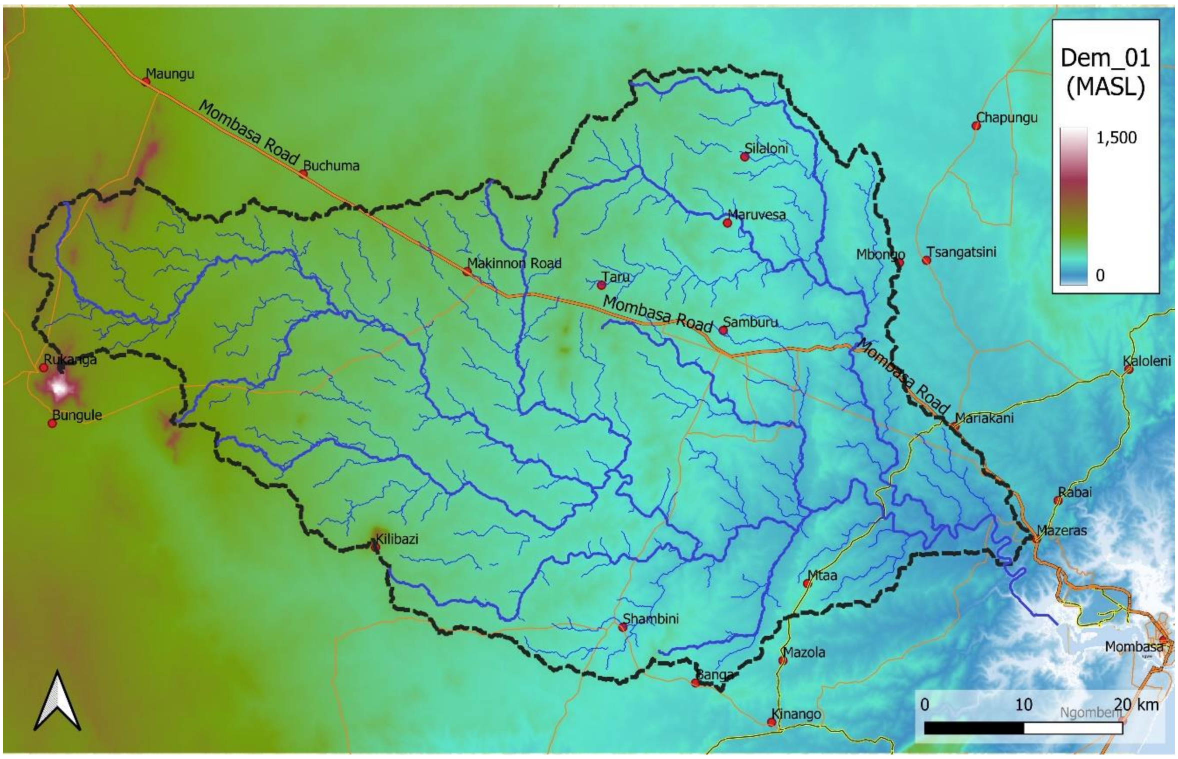


Figure 7-15. Digital elevation map. Source: HydroSheds

28 https://www.hydrosheds.org/

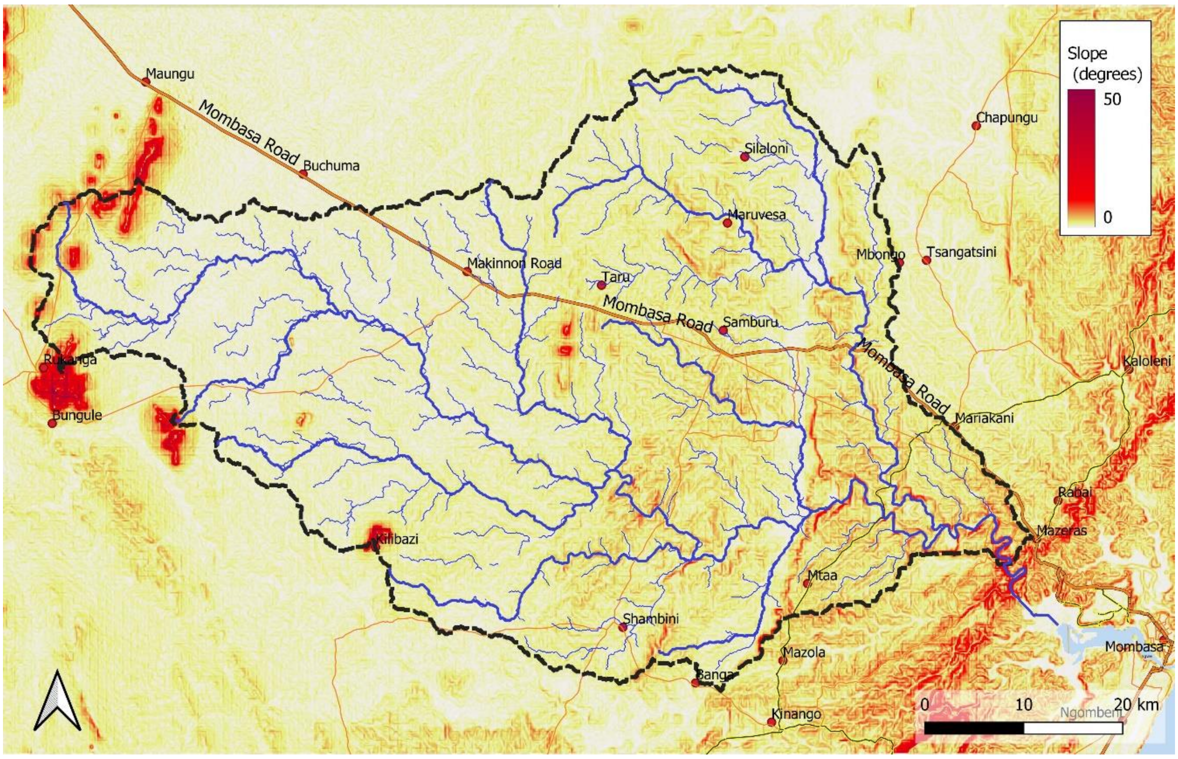


Figure 7-16. Slope map derived from the digital elevation map.

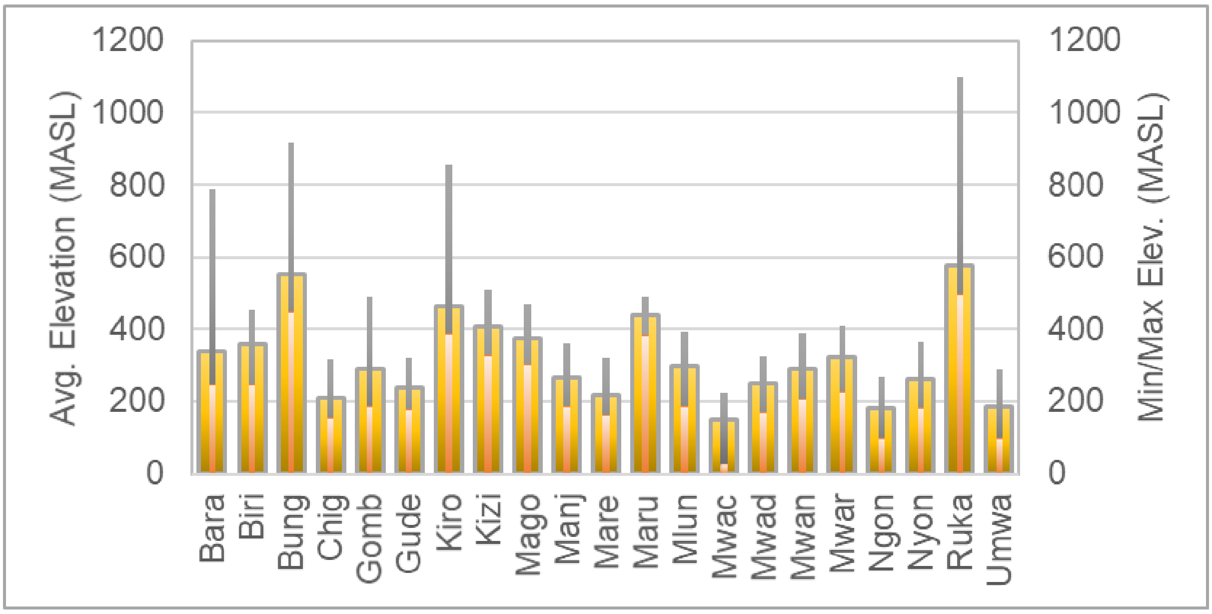


Figure 7-17. Average and minimum and maximum elevation in the 21 sub-catchments.

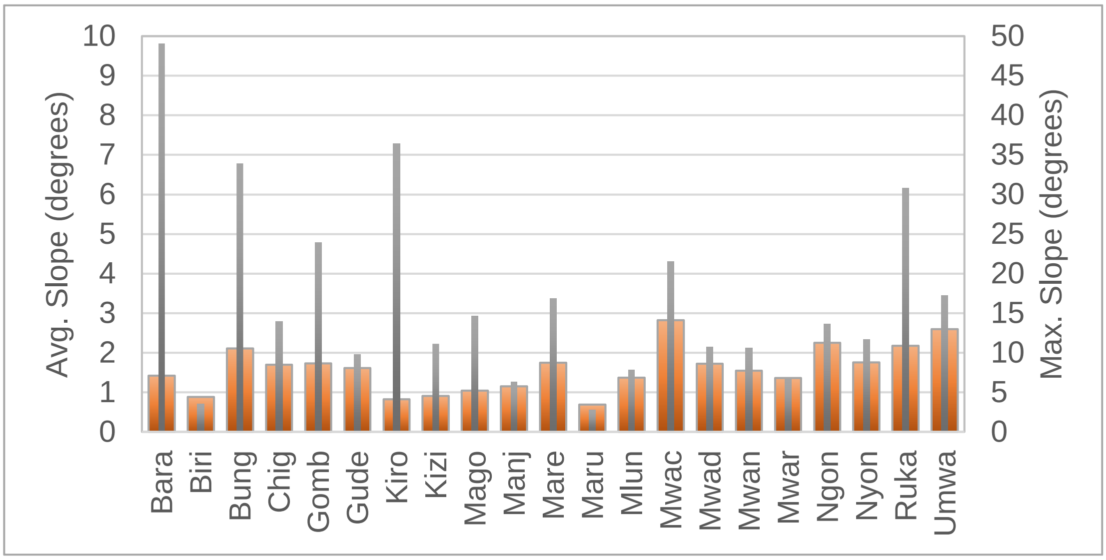


Figure 7-18. Average and maximum slopes in the 21 sub-catchments Note: Y-axis left and right are on different scales.

Soils

There is limited local information available on the soil characteristics of the Mwache Dam catchment. The ESIA (2014) mentions: "The soil types have a strong correlation with the geology and topography of the region and differ widely in depth, texture, physical and chemical properties with variations running parallel to the coastal line due to sedimentation process." It was therefore decided to rely on the HiHydroSoil global database as developed by FutureWater. HiHydroSoil is based upon the ISRIC SoilGrids and the FAO's Global Atlas of Soils.

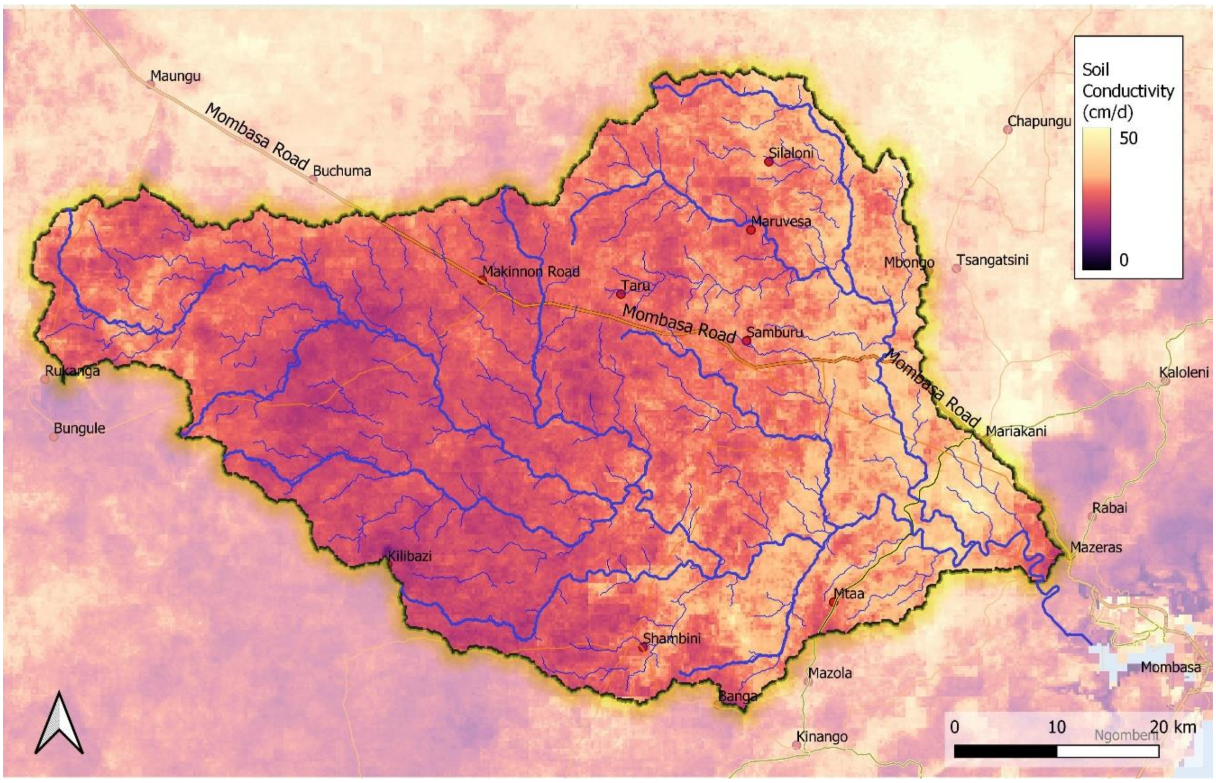


Figure 7-19. Soil conductivity. Source: HiHydroSoil

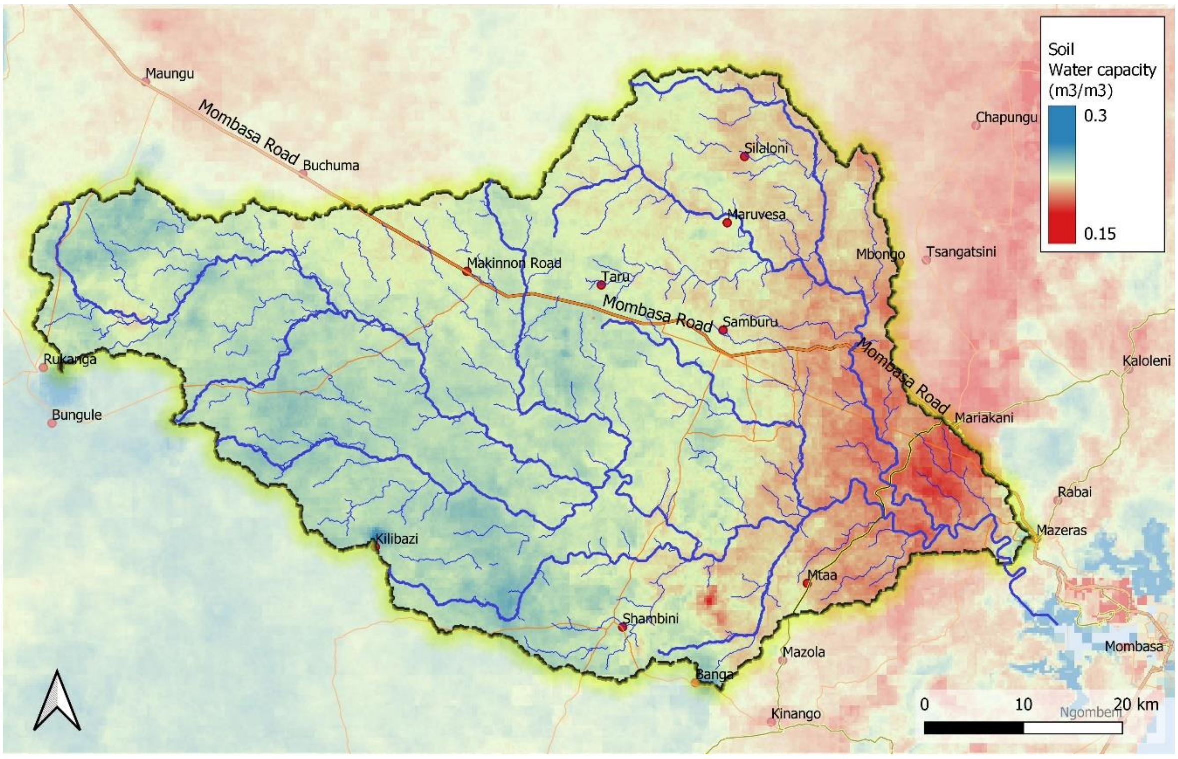


Figure 7-20. Soil water holding capacity. Source: HiHydroSoil

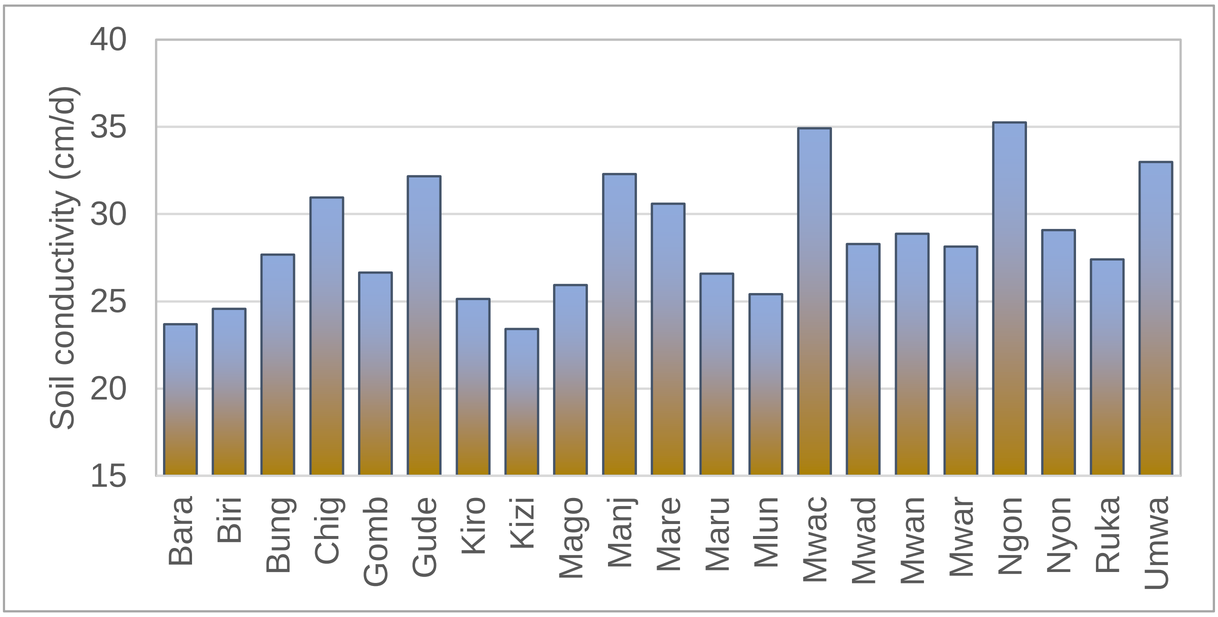


Figure 7-21. Average soil conductivity for the 21 sub-catchments. Source: HiHydroSoil

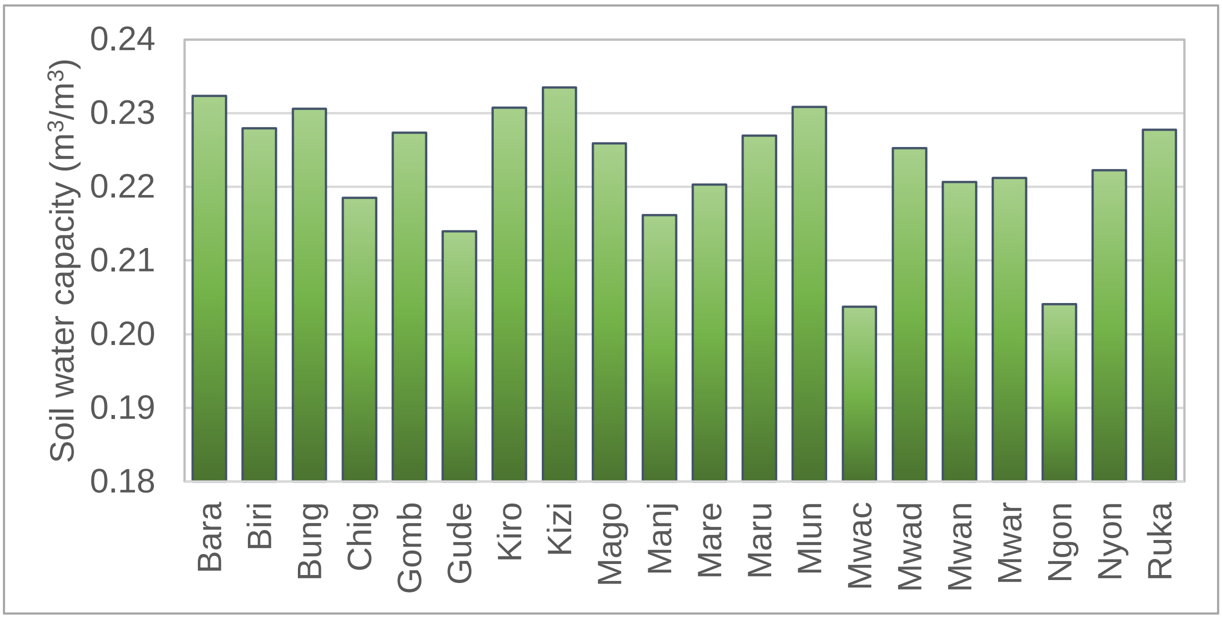


Figure 7-22. Average soil water holding capacity for the 21 sub-catchments. Source: HiHydroSoil

Streamflow

Streamflow data hardly exist for the Mwache Dam catchment area. The Detailed Design Report (CES, 2014) concluded that hydrological data for Mwache River exist only for the period 1976 to 1990 and was recorded at River Gauging Station (RGS) 3MA03 (39°30'44" E, 3°57'06"S) which was located a few kilometers upstream of the proposed dam on Mwache River. Data from this station has also been used in other work in this catchment supported by the World Bank (Taner, Ray & Brown, 2019). This station was later abandoned. The Detailed Design Report was based on the analyses of discharge records at this station. The study also used "Synthetic Generation of Observed Series", although what method has been used remains unclear.

Also for the ESIA report, synthetically generated monthly stream flow data were used (Figure 7-23 and Table 7-2). Overall statistics mentioned in these studies are:

- Mean annual flow = 113.41 MCM;
- Design flood = 2,760 m^3/s;
- Diversion flood = 80 m^3/s, both based on a 25-year return period.

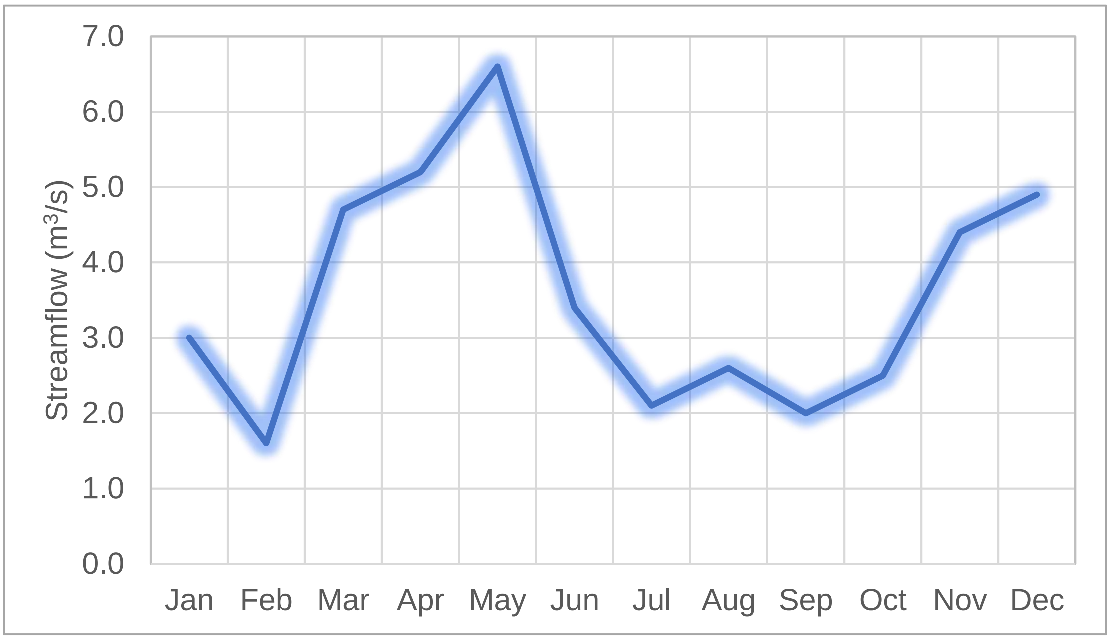


Figure 7-23. Mean monthly streamflow for the Mwache River for the period 1976 to 1990 recorded at River Gauging Station 3MA03. Source: CES, 2014

Table 7-2. Mean monthly streamflow for the Mwache River for the period 1976 to 1990 recorded at River Gauging Station 3MA03. Source: CES, 2014.

	$m^3 s^{-1}$	m^3	mm
Jan	3.0	8,035,200	0.36
Feb	1.6	3,870,720	0.17
Mar	4.7	12,588,480	0.56
Apr	5.2	13,478,400	0.60
May	6.6	17,677,440	0.79
Jun	3.4	8,812,800	0.39
Jul	2.1	5,624,640	0.25
Aug	2.6	6,963,840	0.31
Sep	2.0	5,184,000	0.23
Oct	2.5	6,696,000	0.30
Nov	4.4	11,404,800	0.51
Dec	4.9	13,124,160	0.58
Avg/sum	3.6	113,460,480	0.42

Erosion and Sedimentation

Poor land use practices are a significant cause of degradation in the Mwache Dam catchment and present a risk to the sustainability of the dam. Most farming households do not practice soil conservation measures, which is particularly problematic in more hilly areas which are naturally more prone to erosion. For this reason, the ESIA paid attention to soil erosion and sedimentation issues and incorporated mitigation measures in the design. The study estimates the sedimentation rate based on landcover (varying from 500 m^3/sq km/yr (forest), 1000 (grass land) and 1500 (habitants and roads)). Sedimentation load is estimated and three check dams at suitable sites are proposed to trap the silt and dispose it off at 2-3 years interval. More details of the sedimentation estimates and its disposal plan are given in the respective Sedimentation Management Plan.

The erosion calculation requires several parameters to be estimated that depend on landcover and land management (respectively C-factor and P-factor). To be consistent with the InVEST-based erosion assessment, the same parameters were used in WEAP (see Table 7-3).

Table 7-3. USLE C-factor and P-factor used for the WEAP erosion plugin, baseline scenario

lucode	Class	usle_c	usle_p
11	Forest	0.005	1
12	Deg forest	0.08	1
21	Shrub	0.12	1
22	Deg shrub	0.25	1
31	Grass	0.15	1
32	Deg grass	0.3	1
41	Crop	0.346	0.79
51	Aquatic vegetation	0.002	1
61	Bare	0.4	1
81	Built-up	0.3	1
101	Water	0	1

Mwache Dam

The Mwache Dam will be the first surface bulk water source to supply Mombasa. Its construction starts in 2021. The Mwache Dam was designed to provide potable quality via a water treatment plant comprised of flocculation and coagulation, sedimentation, rapid gravity filtration and chlorination units. Compared to the other sources of water for Mombasa, the cost of treatment will significantly higher due to the amount of suspended material in the water. As explained previously, this suspended load can be reduced significantly through good practices and NbS in the catchment.

For the dam design (*CES, 2014*), Full Reservoir Level (FRL) has been determined after fulfilling the criteria of 75% dependability for Irrigation Supply and 99% dependability for Domestic water which satisfies the project demands. The reliability analysis has been carried assuming 99% reliability for domestic water supply requirement and 75% reliable irrigation supply. The 99 % reliable Gross Capacity is 138.10 MCM which corresponds to Reservoir Elevation at 85.7 m.a.s.l. Reservoir gross storage has been proposed as 138.10 MCM. The design parameters were implemented in WEAP (storage-elevation curve and different levels, see Table 7-4 and Figure 7-24).

Table 7-4. Reservoir parameters used for WEAP (source: Mwache Dam Design report)

Full Reservoir Level (FRL)	El. 85.7 m
Gross Storage at FRL	138.10 MCM
Minimum Draw Down Level (MDDL) for water supply	El. 49.5m,
Operational Level for irrigation supply	El.57m

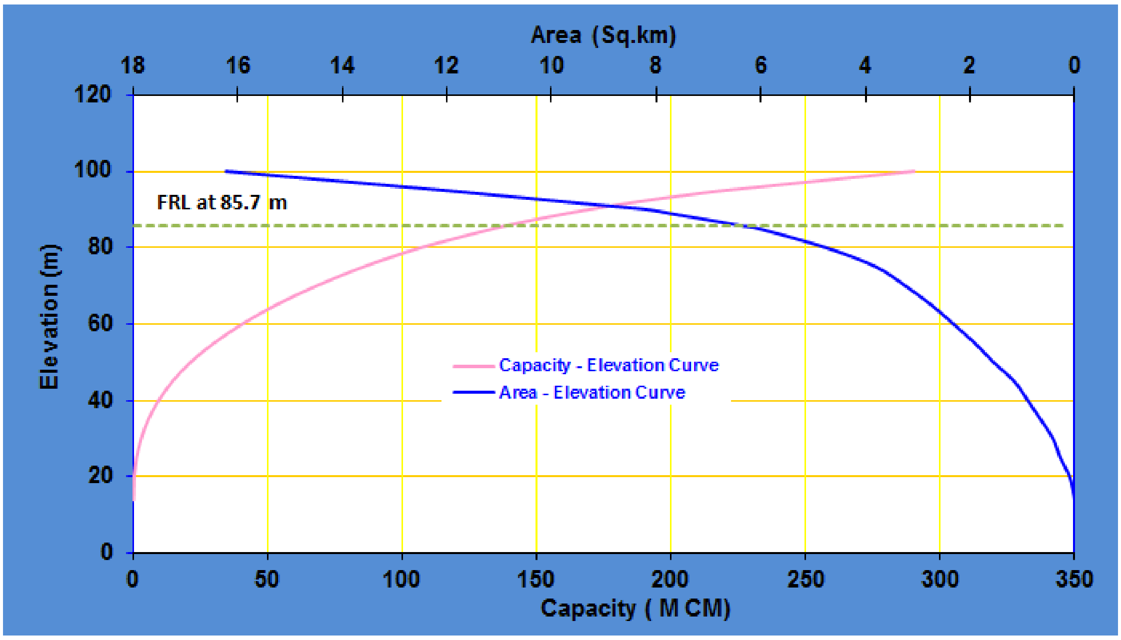


Figure 7-24. Area-Elevation–Capacity Curve at Mwache Dam site. Source: CES, 2014; Fig 1.4.8.

MWACHE DAM CATCHMENT MODEL PERFORMANCE

The data and information as described above was used to develop a hydrological model for the entire Mwache Dam catchment. This model was then used to evaluate the current situation in order to get an initial concept of potential Mombasa Water Fund measures. The same model was then used to assess the impact of various intervention scenarios.

It was decided that the WEAP model was most suitable for the hydrological modeling as it is able to combine and link water demand, allocation and supply under various scenarios. The concept of Hydrological Response Units (HRU) was used as originally introduced for the SWAT model. An HRU is defined as "a portion of a subbasin that possess unique land use/management/soil attributes" (SWAT. 2020).

The HRUs were constructed by overlaying the following features: 21 sub-catchments, 8 land use classes, 5 slope classes,3 saturated conductivity classes and 3 soil water availability classes according to the descriptions in the previous sections. In theory this might lead to 7560 HRUs (21*8*5*3*3). However, many combinations do not exist resulting in a final number of 1108 HRUs.

The WEAP model was set up and populated with data as described above. To demonstrate the versatility of the model to undertake biophysical analysis in order to better understand the current situation some typical screenshots from the output the model generates are shown below.

- Figure 7-25 shows the annual aggregated water balance over the entire Mwache Dam catchment. Obviously, rainfall and evapotranspiration are the biggest components of the water balance. Wetter years (2007, 2020) and dry years (2009, 2016) can be clearly observed. Interesting is that the impact of soil moisture buffering can be seen in terms of accumulated (over all days of the year) "increase" and "decrease" in soil moisture.
- Figure 7-26 shows the streamflow in all sections of the Mwache River as daily averages over 20 years. Low flows and high flows can be observed. Note that the dynamics are

somewhat less presented in this Figure as daily averages over 20 years are shown. Further analysis on low and high flows will be provided later in this chapter.

- Figure 7-27 provides a graphical representation of the mean annual streamflow in all streams and rivers as averages in the year

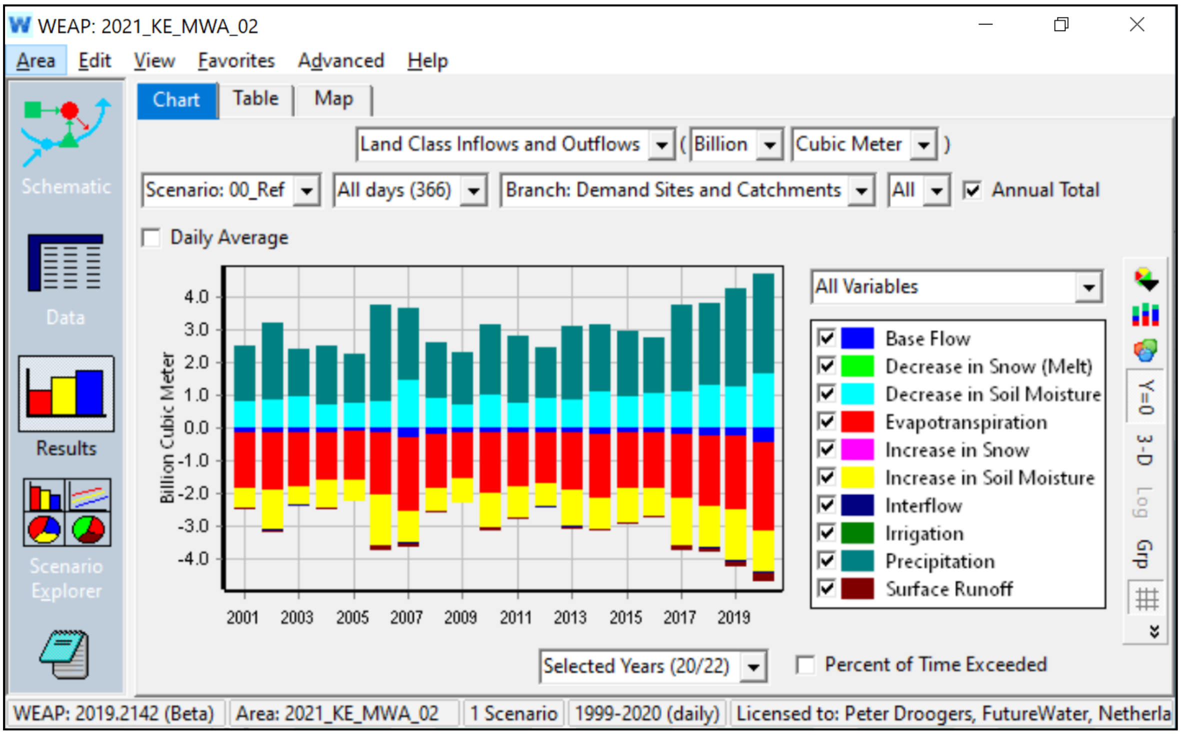


Figure 7-25. Annual water balance aggregated over the 21 sub-catchments, the 6 land use classes and the 1108 HRUs.

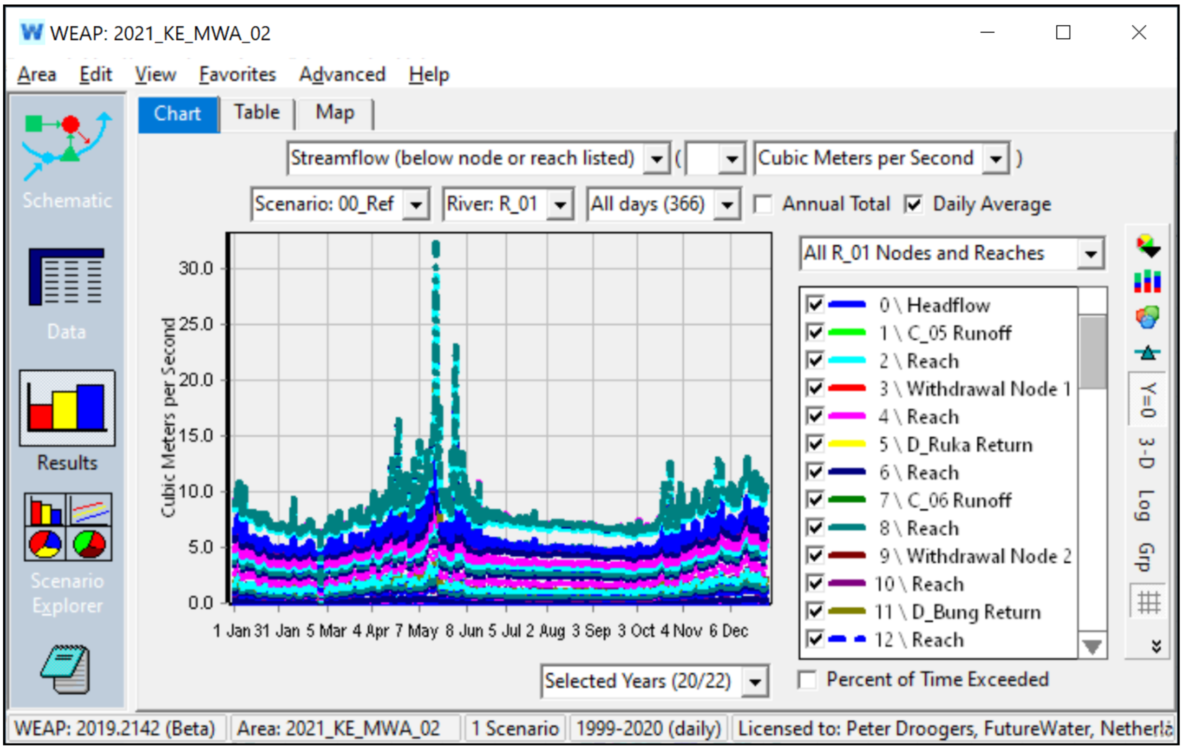


Figure 7-26. Streamflow in all sections of the Mwache River for the baseline case.

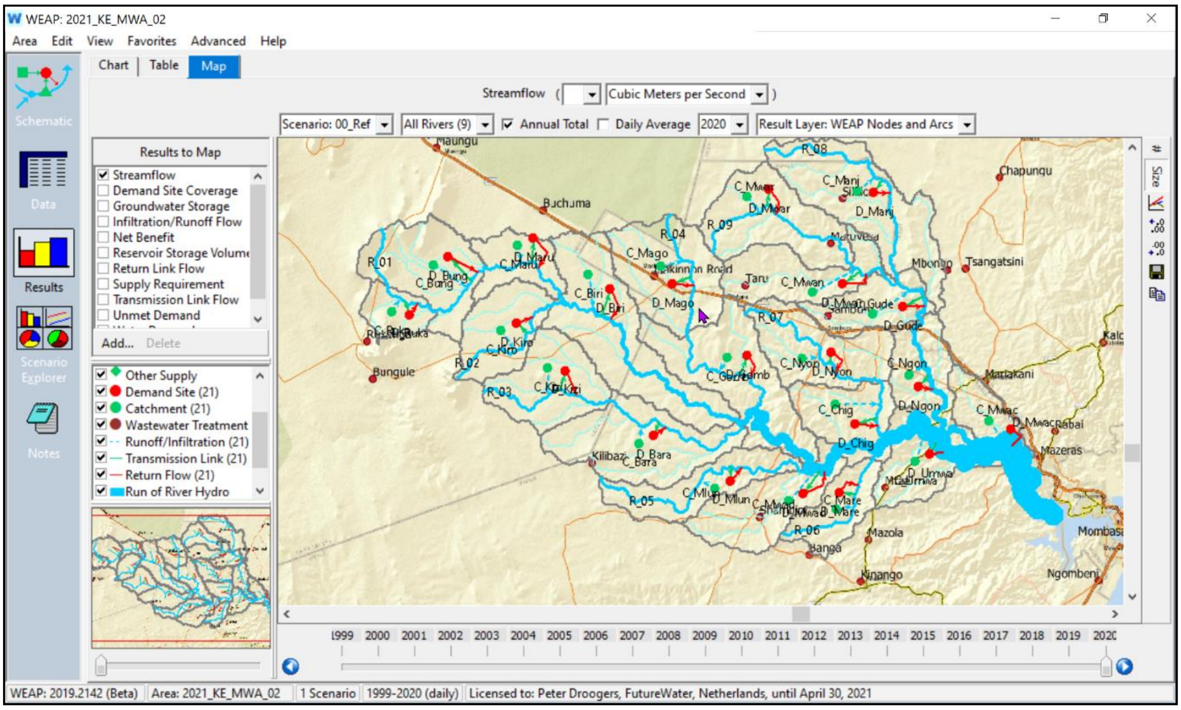


Figure 7-27. Streamflow for all rivers in the Mwache Dam catchment for the baseline case. Thickness of the rivers indicate the streamflow in the year 2020.

For assessing hydrological model performance, there are typically two approaches that depend on purpose of the modeling exercise:

- Hydrological models that support design of infrastructure (like for example Mwache Dam), are typically simple and empirical rainfall-runoff models. These are typically calibrated using observed flow data, as accurate outcomes of absolute flows can be critical to prevent mistakes in the design.
- Hydrological models that support strategic and scenario analysis are recommended to be physically-based and distributed, as these perform better under conditions for which they were not calibrated and can thus be used for future conditions. Model performance should be evaluated based on their ability to simulate the key processes in the area of study.

The physically-based soil moisture module and other modules in WEAP model have demonstrated in many previous studies good performance for scenario analysis. It can thus be assumed that model output inaccuracies are dominantly caused by possible errors in the input data. As discussed above, the climate data, elevation data, soil and land cover data can be considered the best available datasets and outperform previously used data for this catchment.

Still, comparison of the simulated flows with the only available "observed" streamflow data from the CES 2014 report have been performed. As indicated in the previous section, those data were reported as "Synthetic Generation of Observed Series" Figure 7-28 indicates that the observed and simulated average mean monthly streamflow are quite comparable in monthly trends. In general, the simulated streamflows are substantially higher compared to the measured ones. Note however, that the catchment has changed since then, and the period of which the records were taken (1976-1990) does not overlap with the period of the simulation for current conditions (2001-2020). Looking at the variation between years, it is clear that the last few years were wetter compared to the other years (Figure 7-29). Leaving out those last wet years, the observed and simulated streamflow are remarkably comparable (Figure 7-29).

For the reasons discussed here, further in-depth calibration/validation of the model is hampered by the lack of more recent flow records. Moreover, the period of gauging (1976-1990) reflects past land cover, population, water extraction and climate conditions. Those data are not well known and are a major restriction in setting up any model for those periods. Since the model will be used predominantly for scenario analysis, i.e. comparing one option to another, the focus is on comparing relative differences. As shown previously (e.g. Droogers et al., 2008[29]; Simons et al, 2017[30]) conclusions drawn from scenario analysis are much more reliable than absolute model predictions (relative vs. absolute model accuracy). So, in general, we can assume that the WEAP model can therefore be used to further asses the current situation and to undertake scenario analysis.

---

[29] Droogers, P, A. Van Loon, and W. W. Immerzeel. 2008. Quantifying the impact of model inaccuracy in climate change impact assessment studies using an agro-hydrological model. Hydrol. Earth Syst. Sci., 12, 669–678, 2008

[30] Simons, G. 2017. Impacts of climate change on water and sediment flows in the Upper Tana Basin, Kenya

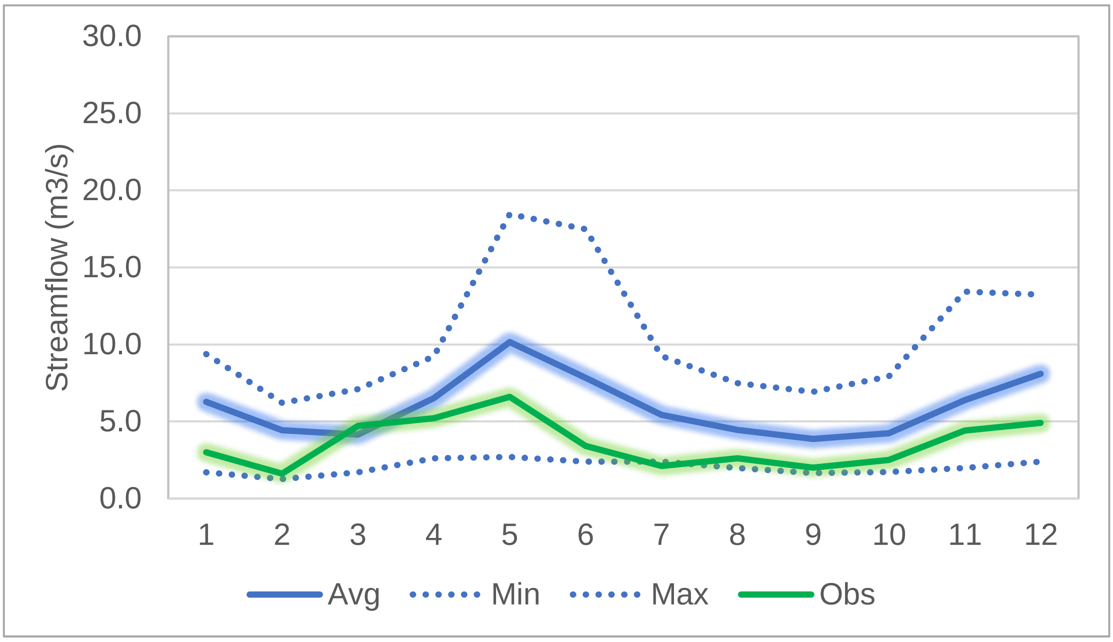


Figure 7-28. Observed (in green) and simulated (blue) monthly average streamflow. Simulated minimum and maximum (90%) flows are also shown. Observed is obtained from the period 1976 to 1990 as presented in the CES (2014) report. Simulated is based on daily runs over 20 years (2001-2020). Note that "Observed" is reported as "Synthetic Generation of Observed Series"

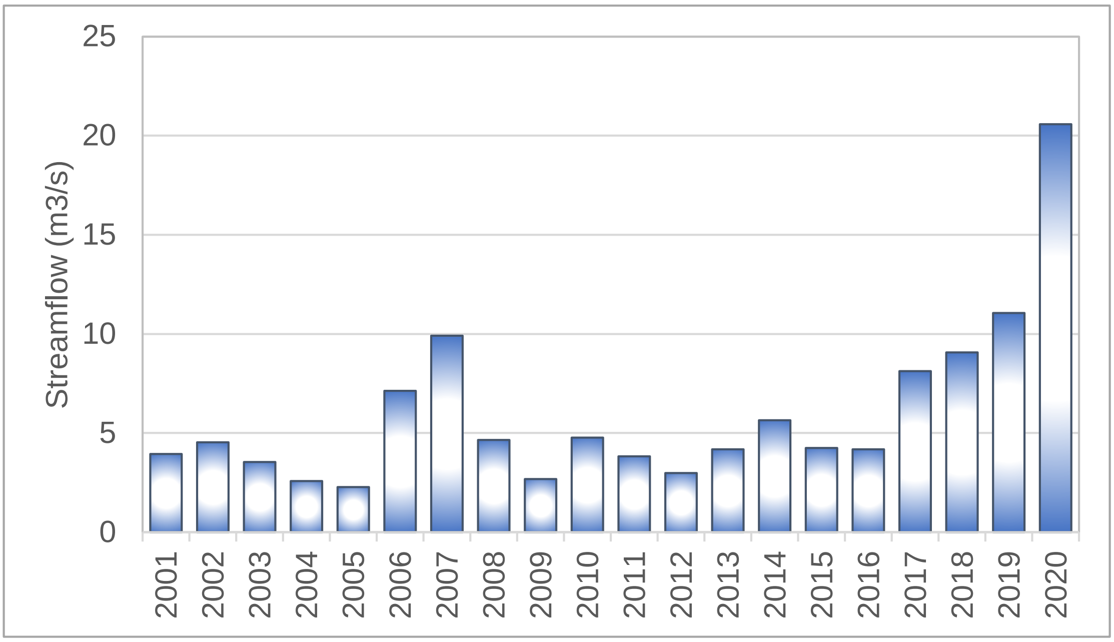


Figure 7-29. Annual average streamflow of the Mwache River at the point of the proposed dam. Data based on the WEAP model.

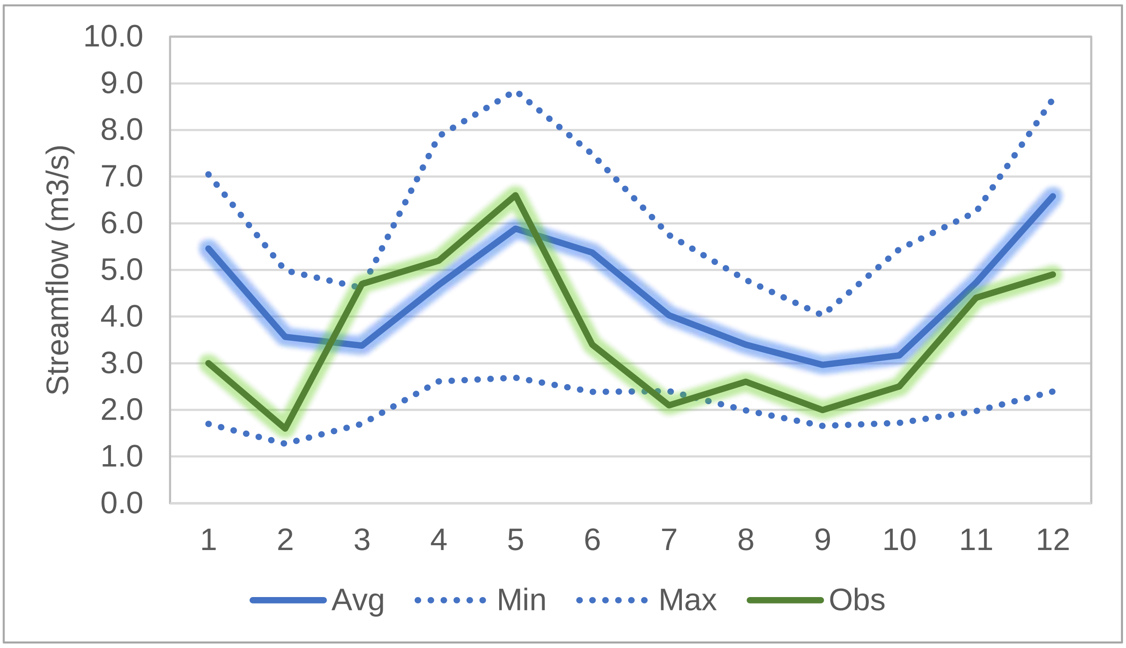


Figure 7-30. Same as Figure 7-28 but here for the modelled years 2001-2016. Note that y-axis here is different from the one used in Figure 7-28.

BIOPHYSICAL ANALYSIS: CURRENT SITUATION

Highlights:

- Total catchment runoff is about 75 mm per year (~ 270 MCM) and has a big spatial and temporal variation
- Without any reservoir, a water demand of 250,000 $m^3 d^{-1}$ (including a minimal environmental allocation) could only be met (hypothetically) on 75% of the days
- Water quality is quite poor mainly due to absence of wastewater management infrastructure
- Erosion shows a high spatial and temporal variation and results presented can be used to focused actions for the Mombasa Water Fund

The WEAP model was used to assess the current status of the Mwache Dam catchment in terms of hydrology and erosion. This included an evaluation at high temporal resolution (daily over a period of 20 years) and various spatial resolutions (entire catchment, sub-catchment, land cover specific, and calculation unit-level - HRUs).

The following four aspects are discussed below in separate sections:

- Water yield and runoff components
- Water demand and supply
- Water quality
- Erosion

TOTAL CATCHMENT RUNOFF

Highlights:

- Total catchment runoff is about 75 mm per year (~ 270 MCM).
- Total catchment runoff shows quite some variation that is a function of complex hydrological features as rainfall differences, land covers, soils and slopes.
- Fast surface runoff (trigger of erosion) is on average 20% of total runoff, but huge variation within the catchment.

To understand better what kind of potential options might be interesting in the context of the Mombasa Water Fund a good understanding of the hydrological characteristics of the catchment is needed. As discussed previously, measurements are always restricted in (i) time, (ii) space and (iii) processes (for the Mwache Dam catchment flow measurements are very scarce and no recent multi-year flow records are available). Figure 7-31 to Figure 7-36 illustrate the hydrological response of the basin in time and space based on the model outputs at daily temporal resolution and high spatial resolution (HRU-level).

For interpreting the outcomes, it is important to understand the distinction between the three main streamflow components which are highly relevant for the Mombasa Water Fund. The so-called **fast runoff** is the fraction of the rainfall that does not enter the soil, but flows directly overland into the streams and rivers. Fast runoff is water that is not available for vegetation and will flow directly into streams and rivers. In case of heavy rainfall events and poorly permeable soils, this flow component can cause local or pluvial flooding. Moreover, fast runoff is one of the main triggers of erosion. The **interflow**, sometimes referred to as slow runoff, is the amount of precipitation that infiltrates in the soil and is not evaporated by vegetation and does not flow into the groundwater (recharge). This water ends up at a slower rate in streams and rivers and is often seen as an important regulator of heavy rainfall. At the same time, quite a substantial amount of water that enters the soil will end up being used by vegetation and not ending up in streams at all. Soil conservation measures that target local benefits can therefore result in less water in streams and reservoirs. Obviously, this interflow water ends up in the surface water in a more regulated and less extreme amount. Finally, **base flow** is the amount of precipitation that flows through the soil layer into the groundwater and ends up eventually in streams and rivers through groundwater discharge. The sum of those three flows (fast runoff, interflow, base flow) is referred to as **total catchment runoff** in this report[31].

The Figures and Tables below give a clear picture of the three components of the total catchment runoff. Most interesting is that only a very small fraction of the precipitation ends up in streams and rivers as the majority of the water is consumed by the vegetation. Also, quite some variation in the water yielding regions can be observed which is a function of on the one hand the amount of precipitation and on the other hand caused by the complex hydrological processes influenced by terrain, slopes, vegetation and soil characteristics. The areas where surface runoff is high might be considered as potentially suitable areas for interventions. At the same time converting degraded soils into non-degraded will increase actual evapotranspiration which might lead, if no other measures are taken, into less water

[31] In the SWAT model the term "Net water yield to reach" is used. In WEAP just "water yield" is used. To avoid confusion with system yield (what the infrastructure can supply), we use the term catchment runoff.

ending up in a reservoir. Obviously, in many cases this somewhat negative impact is outweighed by the positive effects of flow regulation, lower flood risk and lower erosion rates.

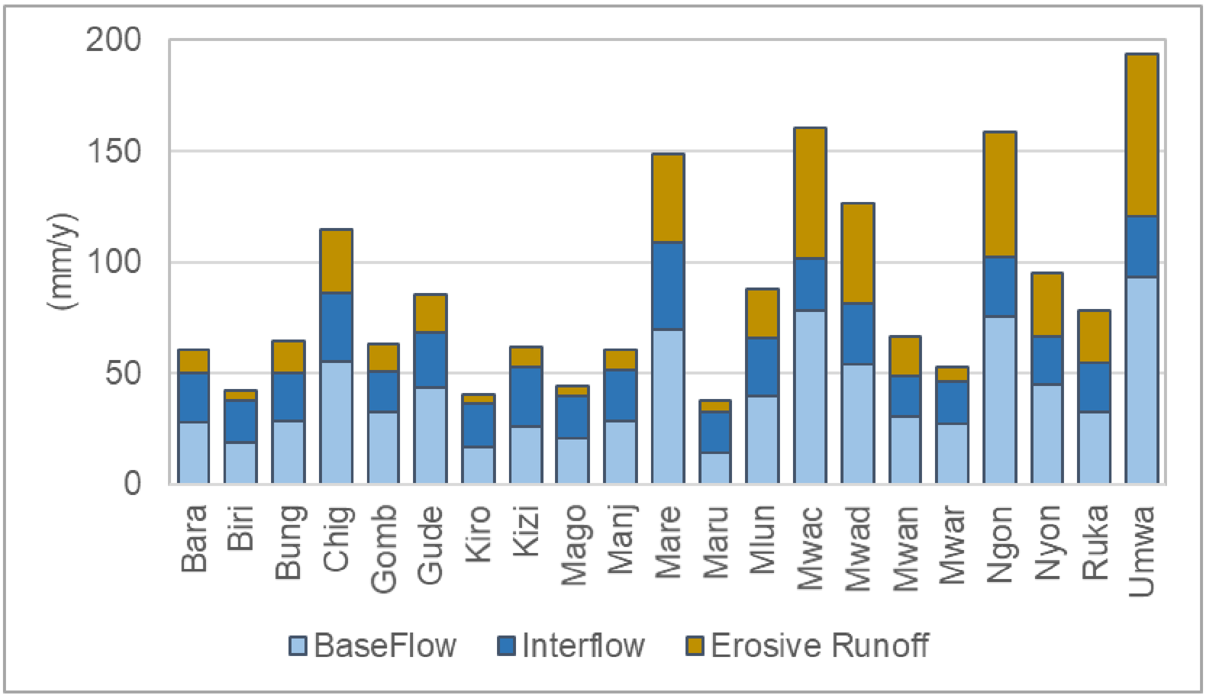


Figure 7-31. Average total catchment runoff for the 21 sub-catchments separated by the three outflow components (fast surface runoff, intermediate interflow and base flow). Results obtained from the WEAP model as annual averages over 20 years (2001-2020).

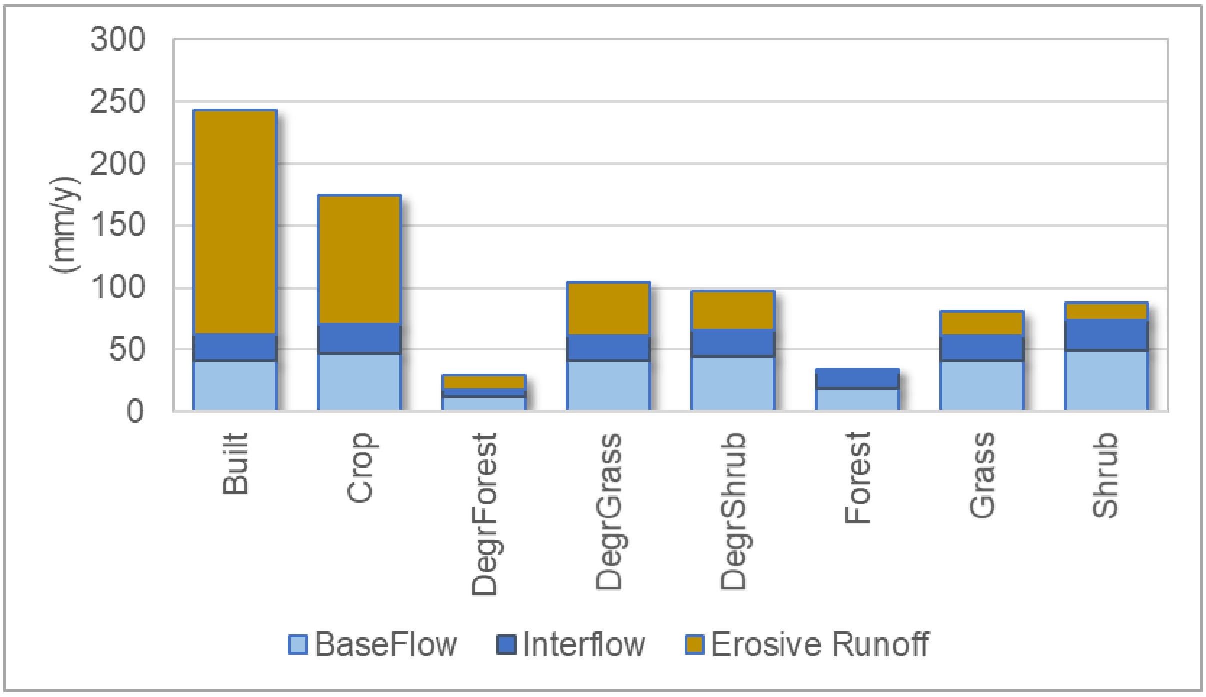


Figure 7-32. Average runoff for the entire Mwache Dam catchment for the dominant land covers separated for the three outflow components (fast surface runoff, intermediate interflow and base flow). Results obtained from the WEAP model as annual averages over 20 years (2001-2020).

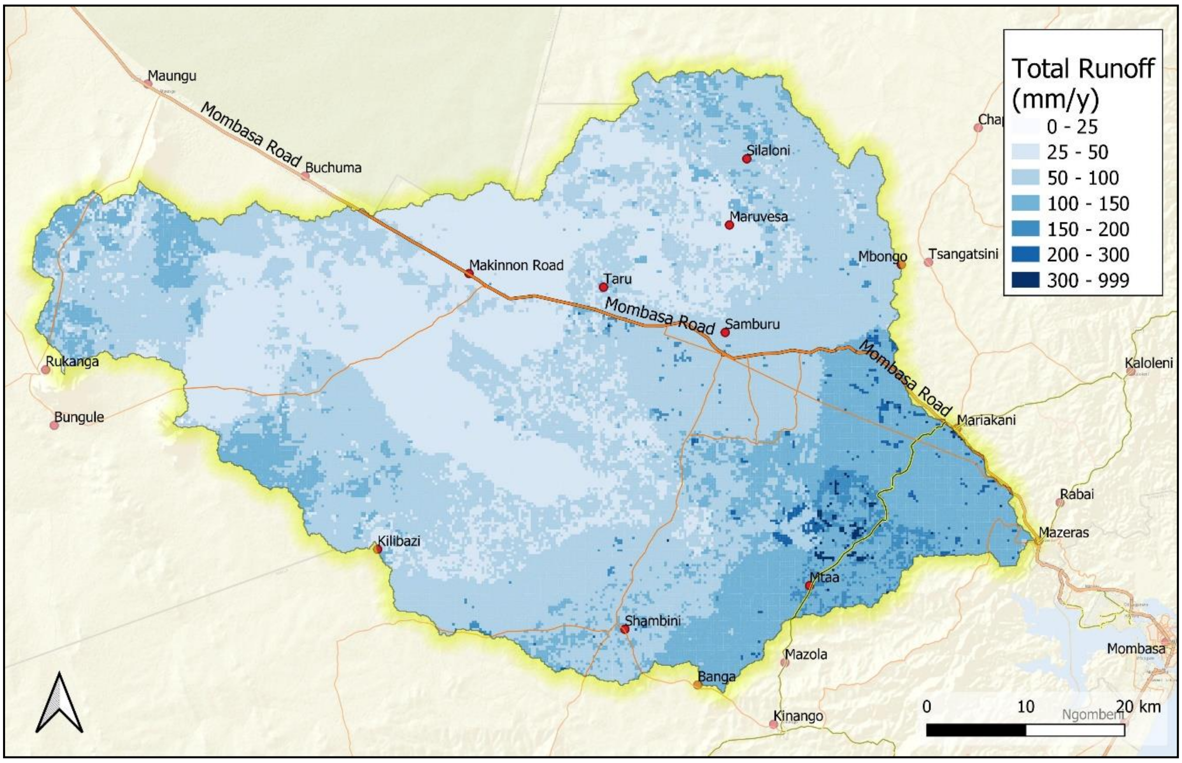


Figure 7-33. Spatial variation in annual average runoff (= sum of fast surface runoff, interflow and base flow) over the entire Mwache Dam catchment. Results obtained from the WEAP model as annual averages over 20 years (2001-2020).

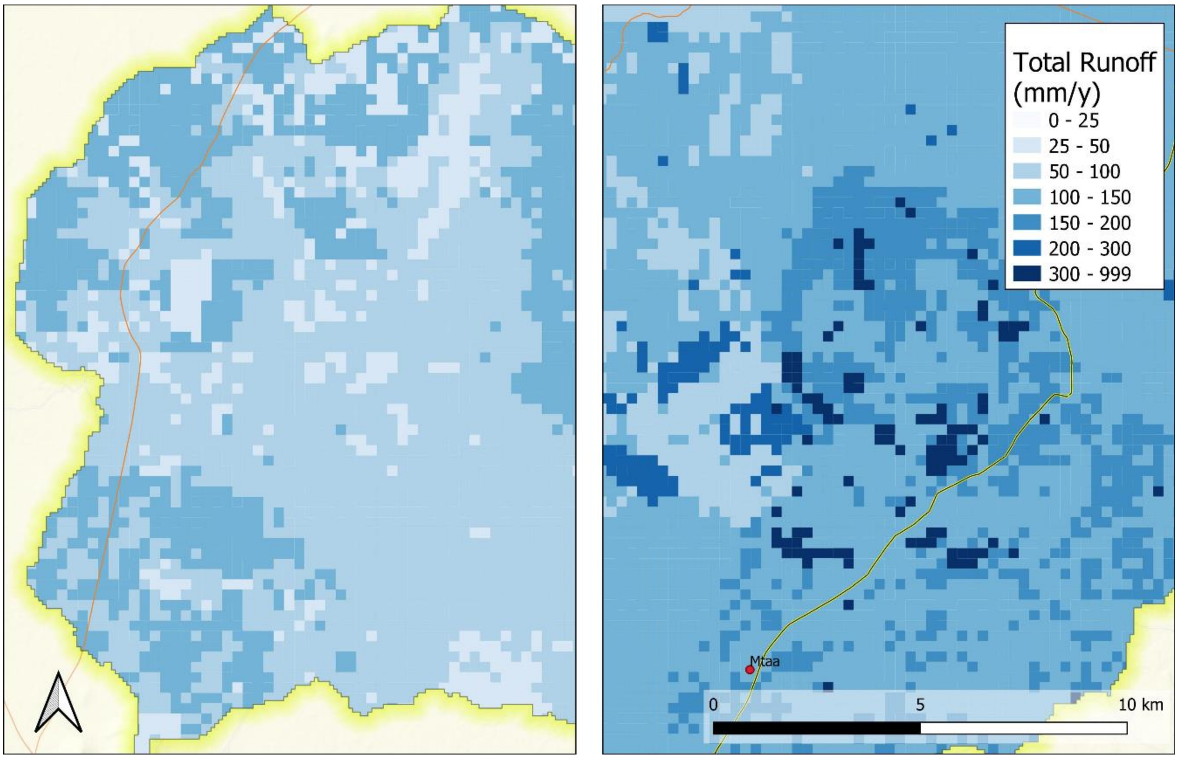


Figure 7-34. Some details obtained from Figure 7-33 indicating small-scale local variation.

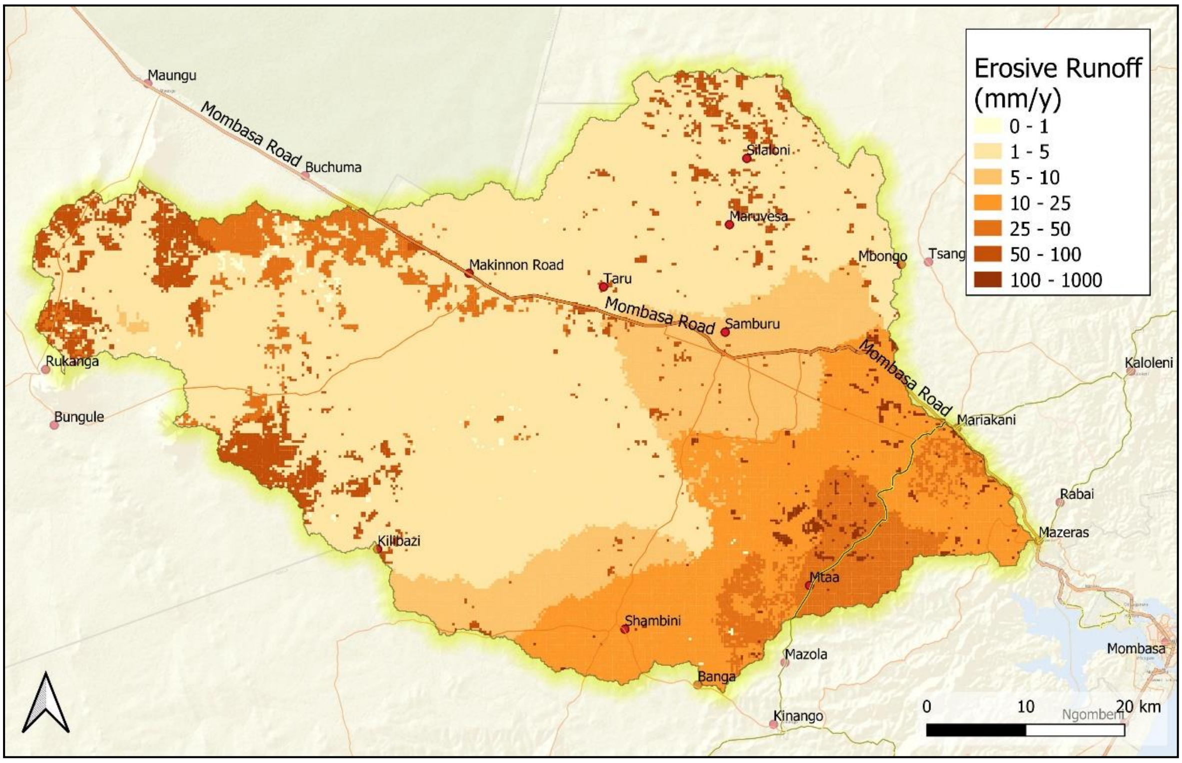


Figure 7-35. Spatial variation in fast surface runoff over the entire Mwache Dam catchment. Results obtained from the WEAP model as annual averages over 20 years (2001-2020).

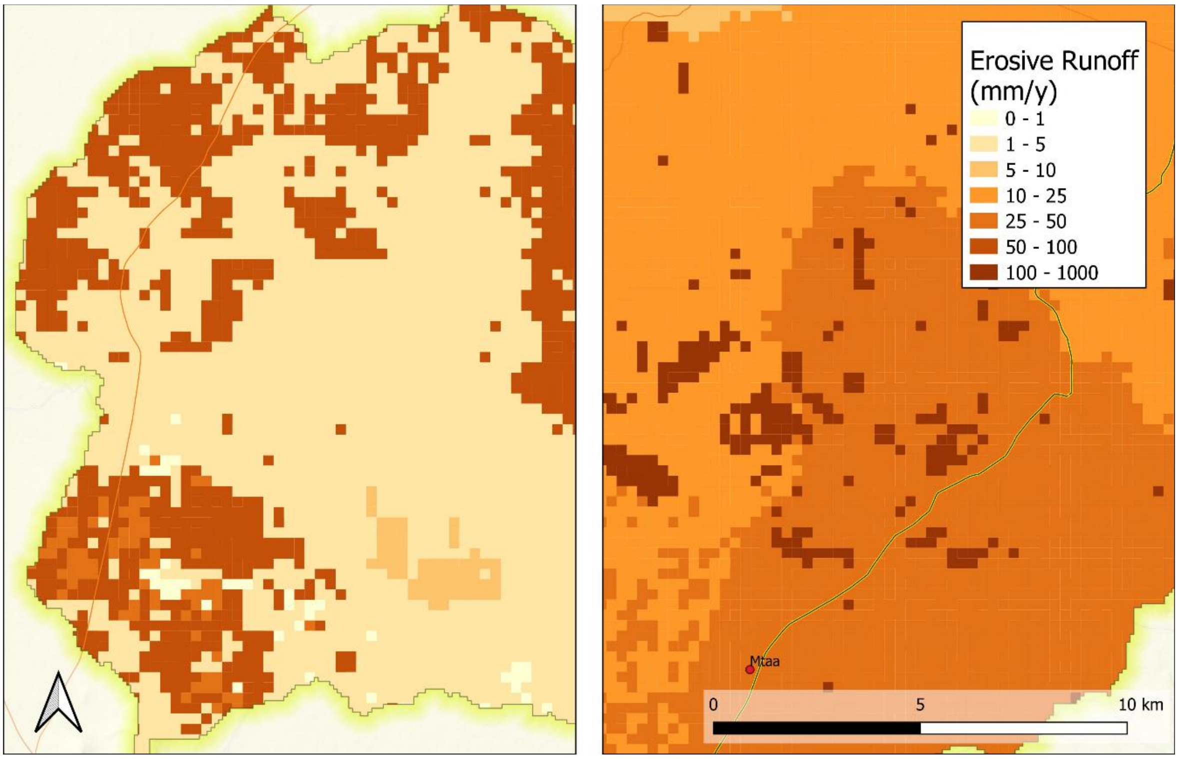


Figure 7-36. Some details obtained from Figure 7-35 indicating small-scale local variation.

WATER DEMANDS AND SUPPLY

Highlights:

- Long term average annual flow at the catchment outlet is 189 MCM per year. Lowest annual flow over the last 20 years was 72 MCM.
- Total average annual flow justifies building a dam to overcome flow variations within a year.
- A daily flow at the outlet of 186,000 m^3d-1 (= 67.9 MCM/yr; defined as the proposed supply to Mombasa) is reached in 75% of the days, considering planned irrigation and a minimal environmental flow of 0.5 m^3d^{-1}.

The estimated water availability from the proposed Mwache Dam is still somewhat unclear. The original detailed design report (CES, 2014) comes to the following conclusion:

- Long-term Annual Average Discharge: 112.8 MCM
- 75% Dependable Annual Discharge: 90.0 MCM
- 90% Dependable Annual Discharge: 80.0 MCM

After this original detailed design study, various updates have been made. An overview is provided by the final report of the Water Fund feasibility study (2020). The report concludes that:

"It is expected to supply 186,000 m^3/d (67.9 MCM/yr) for water supply and water to irrigate high-value crops over an area of about 2000ha. 25,000 m^3/d (9.1 MCM/yr) of this water is ultimately expected to be allocated to Kwale County (Egis Eau 2017). Final design is on-going. An up-dated design review (September 2017), cited in Egis Eau (2017) but not referenced, gives active storage as 127.2 MCM. The Coast Development Authority website states that the supply capacity will be 138,000 m^3/d (http://cda.go.ke/mwache-dam/), and yet officials from CDA estimate the supply capacity at 136 MCM/yr (370,000 m^3/d) with 186,000 m^3/d supplied to Mombasa City."

On top of the 186,000 m^3d^{-1} that is proposed to be the supply to Mombasa, an additional amount of 25,000 m^3d^{-1} is planned to be used for irrigation in the Kwale country. For environmental flows probably another 43,000 m^3d^{-1} is needed (assuming 0.5 m^3d^{-1-}). So total **critical flow is about 250,000 m^3s^{-1}**. Without dam infrastructure, this flow can only be maintained on about 75% of days.

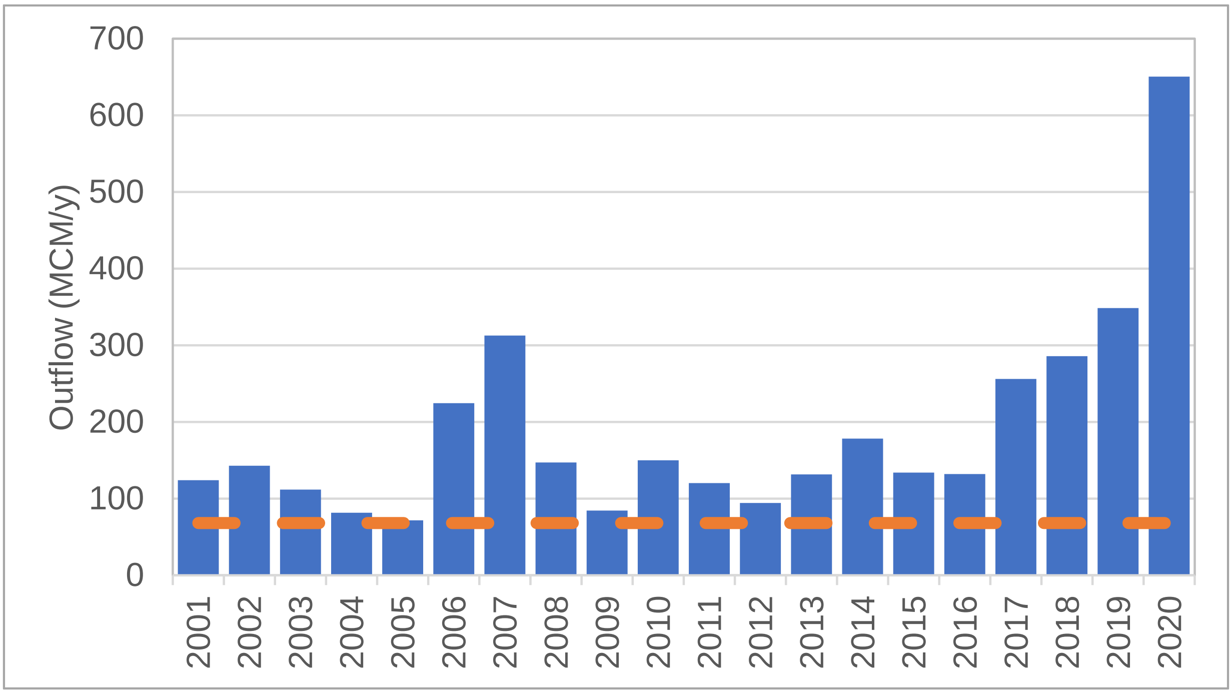


Figure 7-37. Total annual outflow of the Mwache Dam catchment at the location of the proposed dam. The red line indicates the design supply to Mombasa.

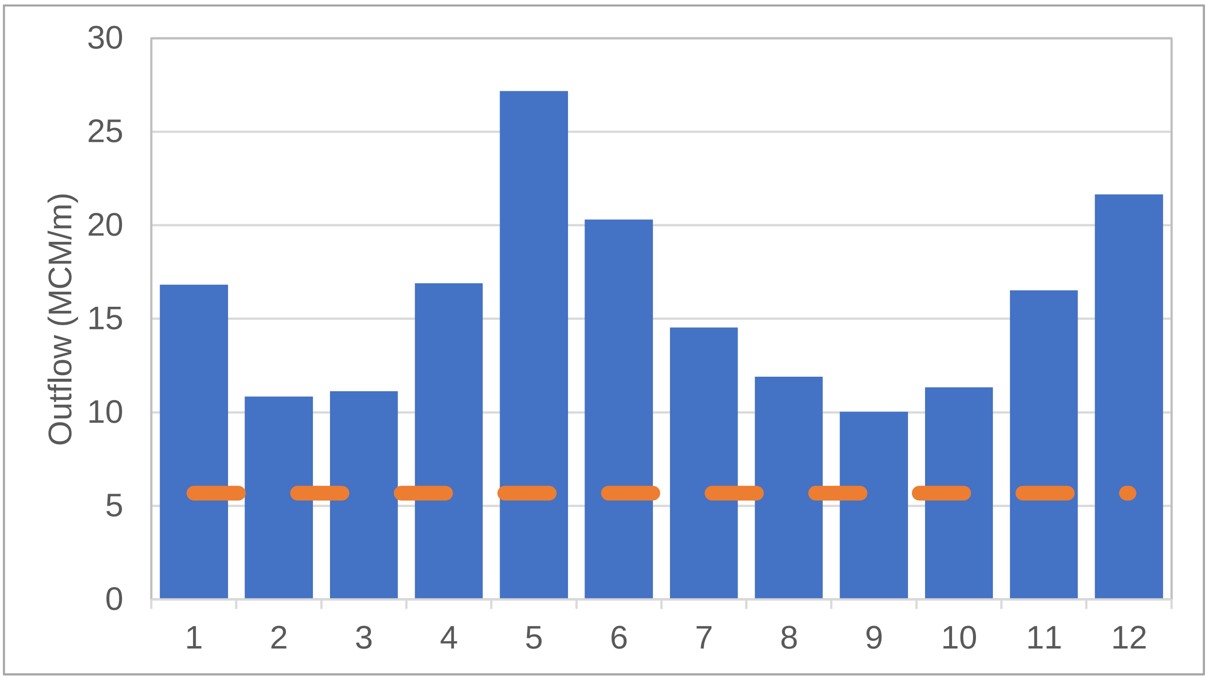


Figure 7-38. Average monthly outflow of the Mwache Dam catchment at the location of the proposed dam. The red line indicates the design supply to Mombasa.

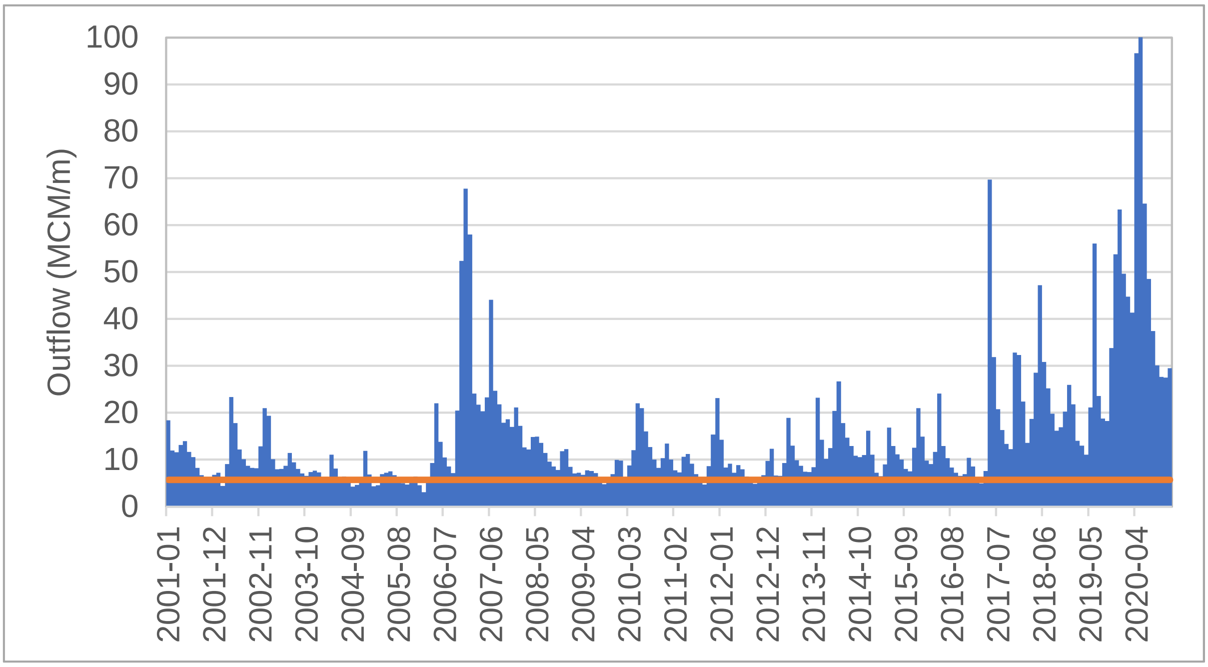


Figure 7-39. Monthly outflow of the Mwache Dam catchment at the location of the proposed dam. The red line indicates the design supply to Mombasa.

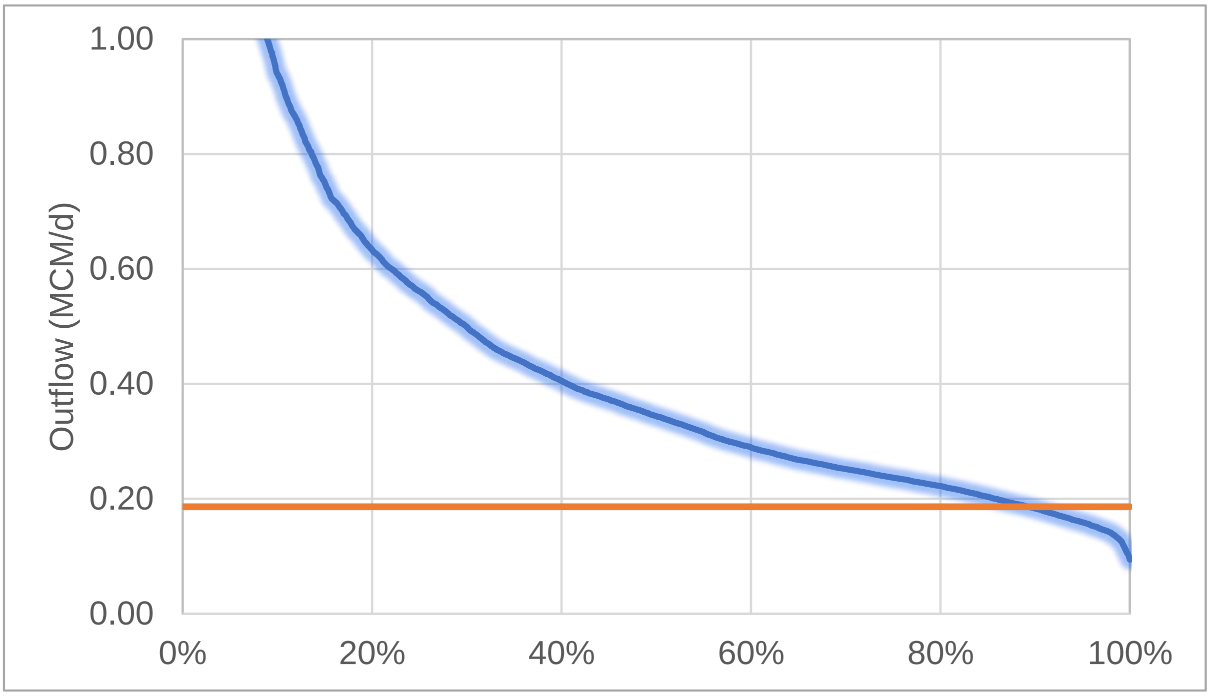


Figure 7-40. Flow duration curve based on daily flow over 20 years (2001-2020) of the Mwache Dam catchment at the location of the proposed dam. The red line indicates the design supply to Mombasa (186,000 m^3 d^{-1}).

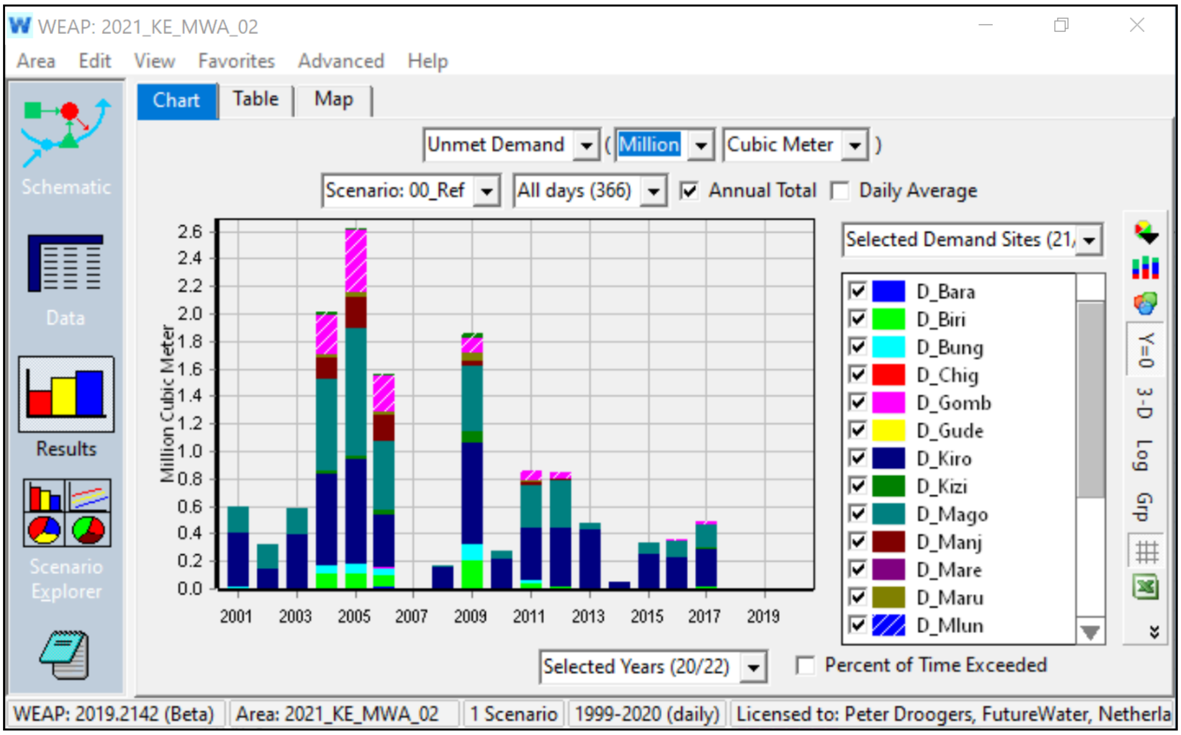


Figure 7-41. Annual current water shortage for the people living in the Mwache Dam catchment. Shortage is based on the demand for domestic use, livestock and small-scale crop cultivation.

WATER QUALITY

Highlights:

- Very limited information and quantitative data on water quality are available
- Phosphorous as an indicator of water quality was implemented in the model
- Results show that water quality is an issue in the catchment

There are no domestic sanitation waste management facilities in the catchment. Although there is hardly any quantitative information on water quality and wastewater produced in the Mwache Dam catchment, qualitative indications and some sparse measurements give reasons for concern. In the absence of reliable data general figures provided by FAO[32] are include in the WEAP model. To undertake a first estimate of water quality issues in the catchment it was decided to focus on only one constituent: phosphorous as a kind of indicator. Based on the FAO publication it was assumed that a value of 6 mg/l phosphorous would be in the runoff water that flows into the streams.

In 1986, the Environmental Protection Agency (EPA) established the following recommended criteria for phosphorus: No more than 0.1 mg/L for streams that do not empty into reservoirs; no more than 0.05 mg/L for streams discharging into reservoirs; and no more than 0.024 mg/L for reservoirs.

[32] Wastewater treatment and use in agriculture - FAO irrigation and drainage paper 47. (1992) http://www.fao.org/3/t0551e/t0551e03.htm

The total amount of phosphorous (as P) generated in the catchment is on average 152,000 kg per year. Total outflow of the catchment is on average 76,000 kg showing the natural cleaning capacity of the streams by various chemical processes[33].

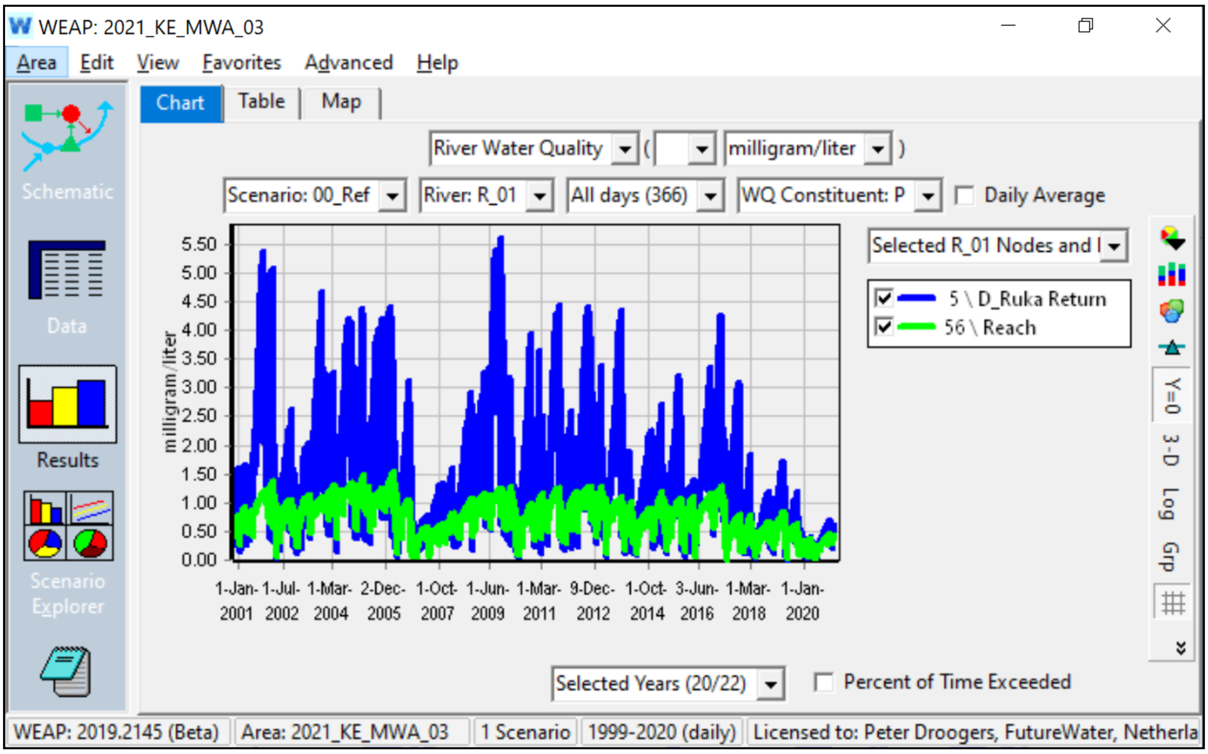


Figure 7-42. Phosphorous concentration at two locations in the Mwache River. Blue: upstream; green: downstream at outlet point.

EROSION AND SEDIMENTATION

Highlights:

- Erosion is highly variable between the different years
- Erosion is concentrated in some specific spots and during specific days
- Results indicates where to take actions in the context of the Mombasa Water Fund

Erosion is a very complex and dynamic process. Previous studies have attempted to assess erosion and sedimentation in the catchment. The results of the sediment yield simulation reported in the Dam Design Review Report concluded that total erosion would be 1.95 million tons per year. Converted to cubic meters, this equates to 1.62 MCM/yr loss of reservoir capacity, assuming all erosion would end up in the reservoir. The Nippon Kai report estimates a total of 46 MCM of sediment accumulation in Mwache Dam after 100 years, assuming that 1.09 – 1.34 MCM will be removed annually from the two check dams.

[33] A first order decay of 0.02 d^{-1} was assumed. $C = C_0 * \exp(-0.02)$. Source: The decomposition rates of organic phosphorus and organic nitrogen in river waters, 2012; Table 3.

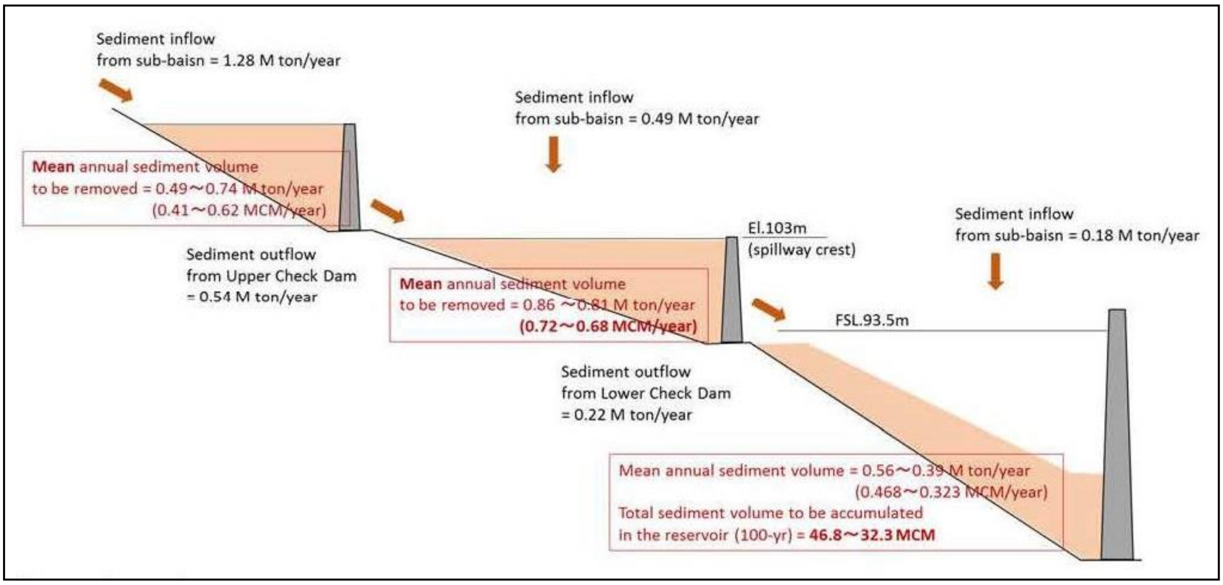


Figure 7-43. Total erosion loadings according to the Dam Design Review Report. Variation show by ~ are somewhat unclear as the source in the report only refers to "consultant".[34]

The Physiographic Survey of Mwache Dam catchment (RTI, 2017) has used the RUSLE approach to create maps of erosion risk. It should be emphasized here that the RUSLE approach is not dynamic (e.g. not depending on actual rainfall conditions, soil moisture etc.). The report provides observations and analysis of conditions in the Mwache Dam catchment. The report identifies various erosion hotspots (Fulungani, Mwashanga, Vitsakafiri, and others), poor farming practices, deforestation, gully/river bank erosion, sand harvesting as the main activities that pose a risk to the Mwache Dam. The report then ranks the sub-catchments by sediment risk. The report indicates that grassland, constituting 89% of the catchment area, has the highest erosion rate under low ground cover conditions (1906 ton/ha/yr), followed by cultivated land which constitutes 7% of the total area (115 ton/ha/yr). The Physiographic Survey concluded that the erosion risk would be in total 4.484 Million tonnes/yr, or an average of around 12.5 t/ha/yr across. However, this appears to contradict the map presented in the study (Figure 7-44), where only very small areas of the catchment were shown to have erosion rates in excess of 10t/ha/yr.

[34] Sediment Management Plan - Main Dam. February 2018. Nippon Koei Co., Ltd., page 3-121

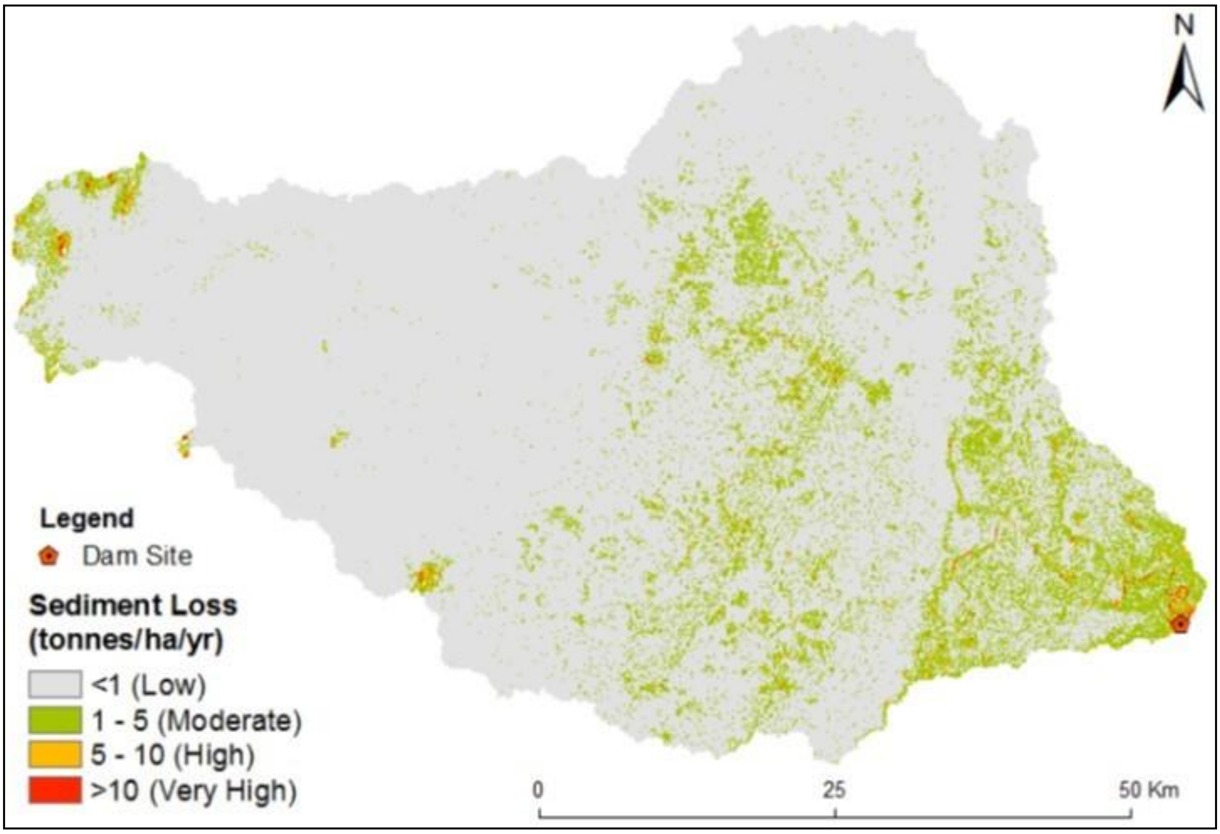


Figure 7-44. Erosion rates according to the Mwache Physiographic Study (RTI International, 2017) (Fig 5-1, p54).

The WEAP erosion plugin was used to assess the erosion rates on a daily basis. The main input parameters required were calculated or assumed as follows:

- Soil erodibility USLE K factor was based on the ISRIC global soil dataset, and close to typical values used for sandy-loam soils
- Slope values are derived from the DEM
- Rain Intensity is the hours per day that rainfall occurs. A default value of 2 hours per day was used
- C USLE factor is the land cover and management factor. Values can range from 1 (fallow/bare land) to 0.001 (forest). Values used are shown in Table 7-3.
- P USLE factor is the supporting conservation practice. Values range 0 (very good manmade erosion resistance facility) to 1 (no manmade erosion resistance facility). Values used are shown in Table 7-3.

The detailed analysis as presented in the Figures and Table below are highly relevant in terms of actions that can be taken in the context of the Mombasa Water Fund. One of the main conclusions of the results presented is that it is very difficult to present one erosion rate level. Figure 7-45 makes it clear that annual and daily variation in erosion is huge. The results indicate that total annual erosion can be as low as 0.07 million tons per year (2009) and up to 0.75 million tons per year (2020). Differences can be attributed to the rainfall and especially to peak rainfall within in a day. One large rainfall event can generate as much erosion as during the rest of the month or even year. Since the WEAP model assesses erosion based on the surface runoff (function of rainfall, soil moisture, slope, land cover, soil type, etc), results can be considered as realistic and especially useful in terms of evaluating alternatives.

Figure 7-46 presents the spatial variation in erosion. The general pattern can be observed as presented by previous studies. However, in contrast to those previous studies, large spatial differences were found. This is in agreement with local observations where erosion is a very local phenomenon.

Figure 7-48 and Figure 7-49 present the same results but split for the 21 sub-catchments and the dominant land covers. As expected, crops, degraded land covers and "build" (which includes bare soils) generate most of the erosion in terms of tons per hectare. Since crops and degenerated are the dominant land covers, total contribution to erosion in the catchments and thus sediment loads in the rivers and stream are highest as well. For the Mombasa Water Fund those results are important to assess where to put focus of adaptations to reduce erosion and this sedimentation of streams, rivers and the dam.

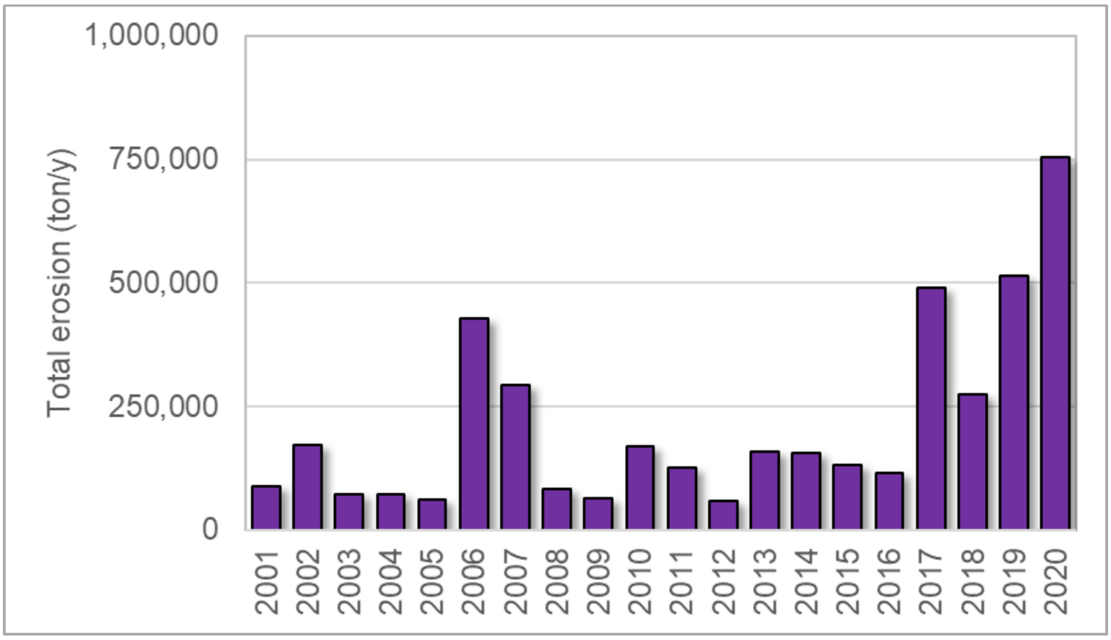


Figure 7-45. Total annual erosion in the Mwache Dam catchment. Results obtained from the WEAP model aggregated over all sub-catchments, land covers and HRUs.

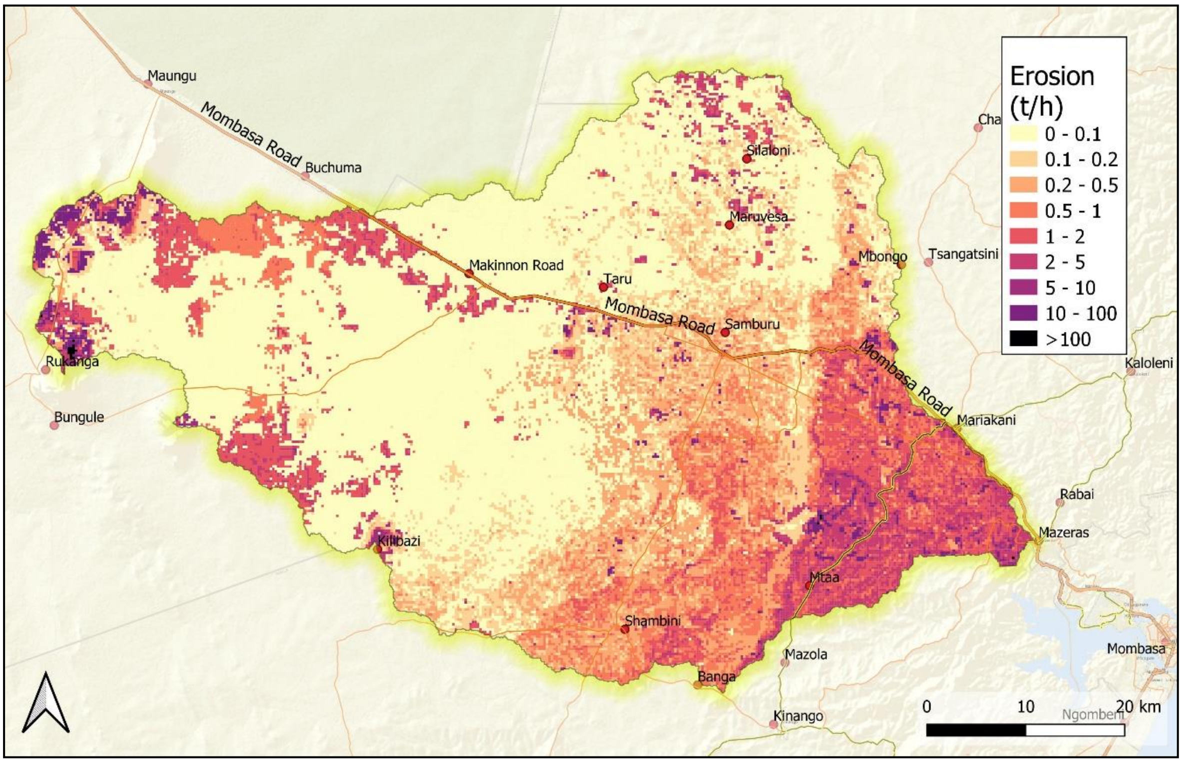


Figure 7-46. Erosion in the Mwache Dam catchment. Results obtained from the WEAP model as annual averages over 20 years (2001-2020).

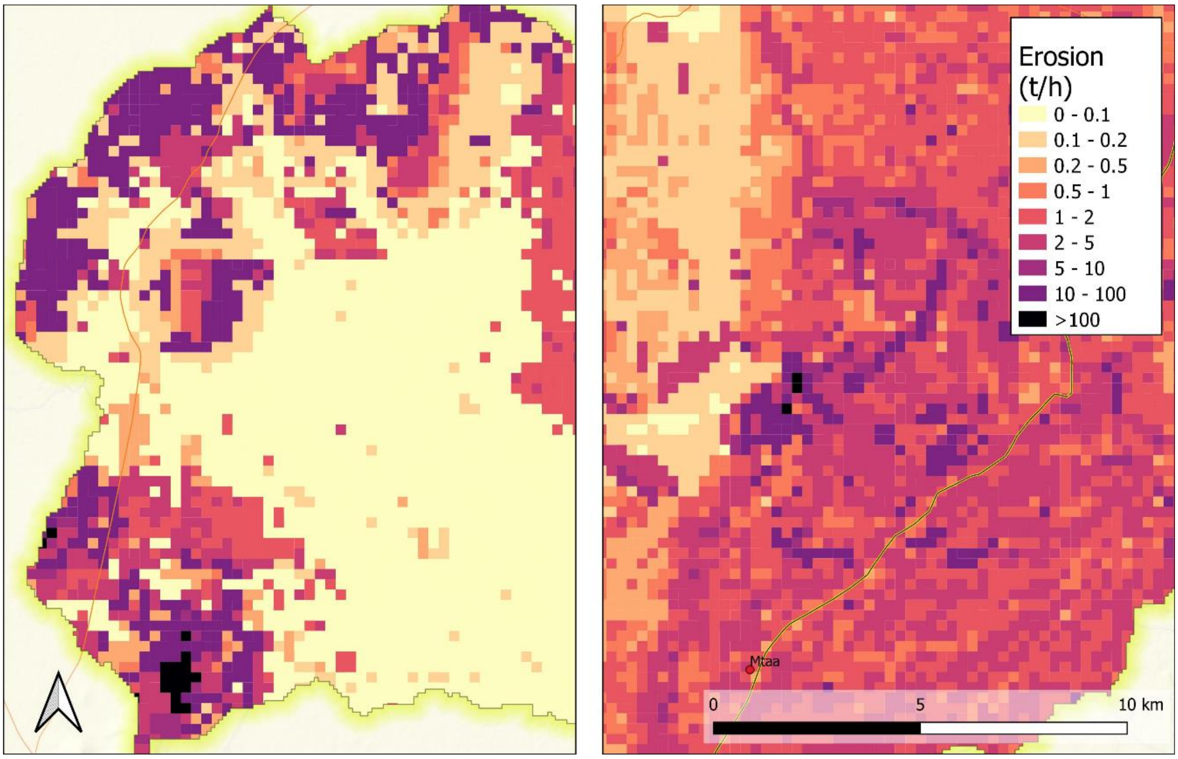


Figure 7-47. Details of Figure 7-46.

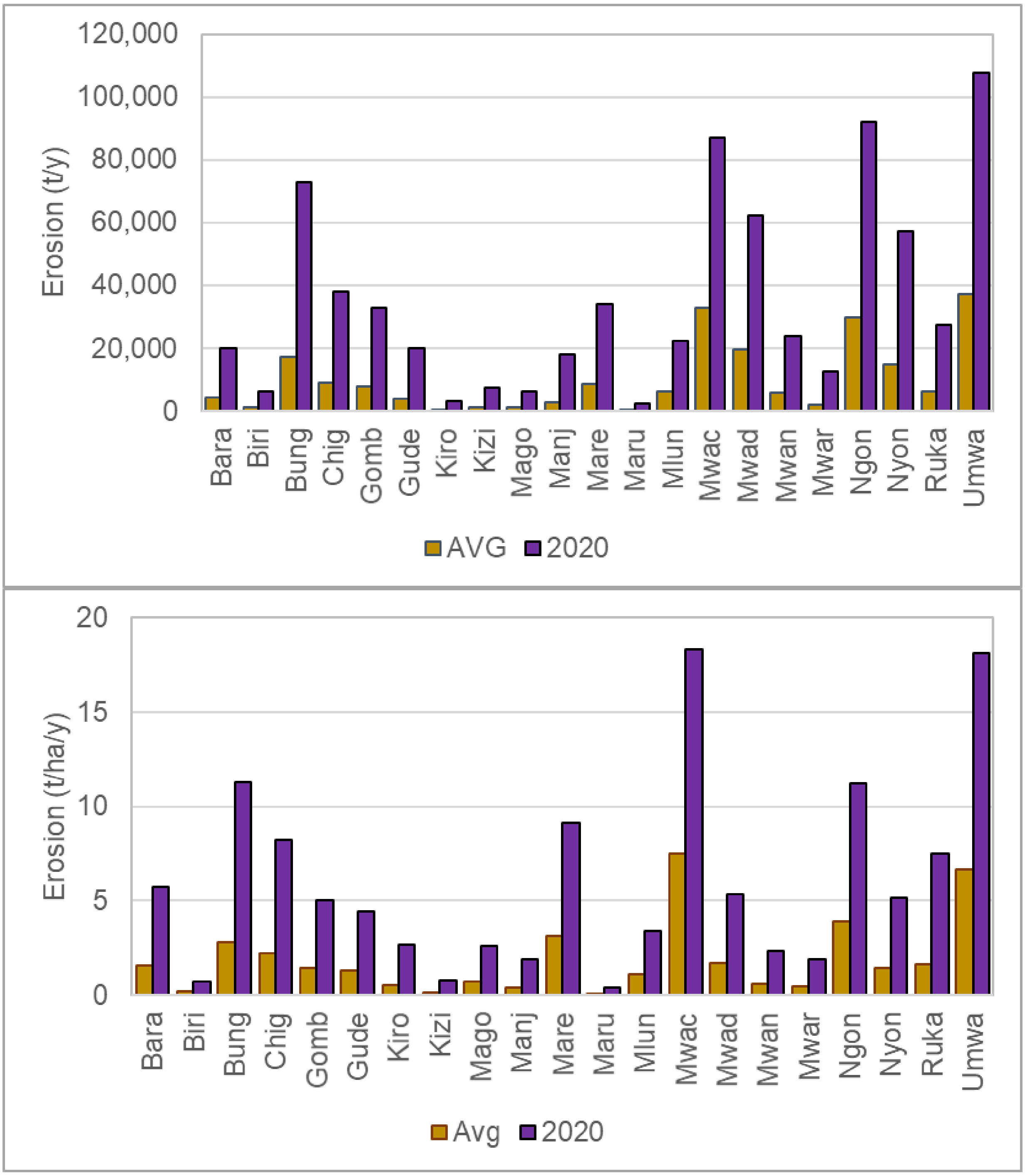


Figure 7-48. Erosion for the 21 sub-catchments in the Mwache Dam catchment. AVG is the average over 20 years (2001-2020); 2020 is the year with the highest erosion rates. Top: total erosion generated in a sub-catchment; bottom: erosion rates per hectare.

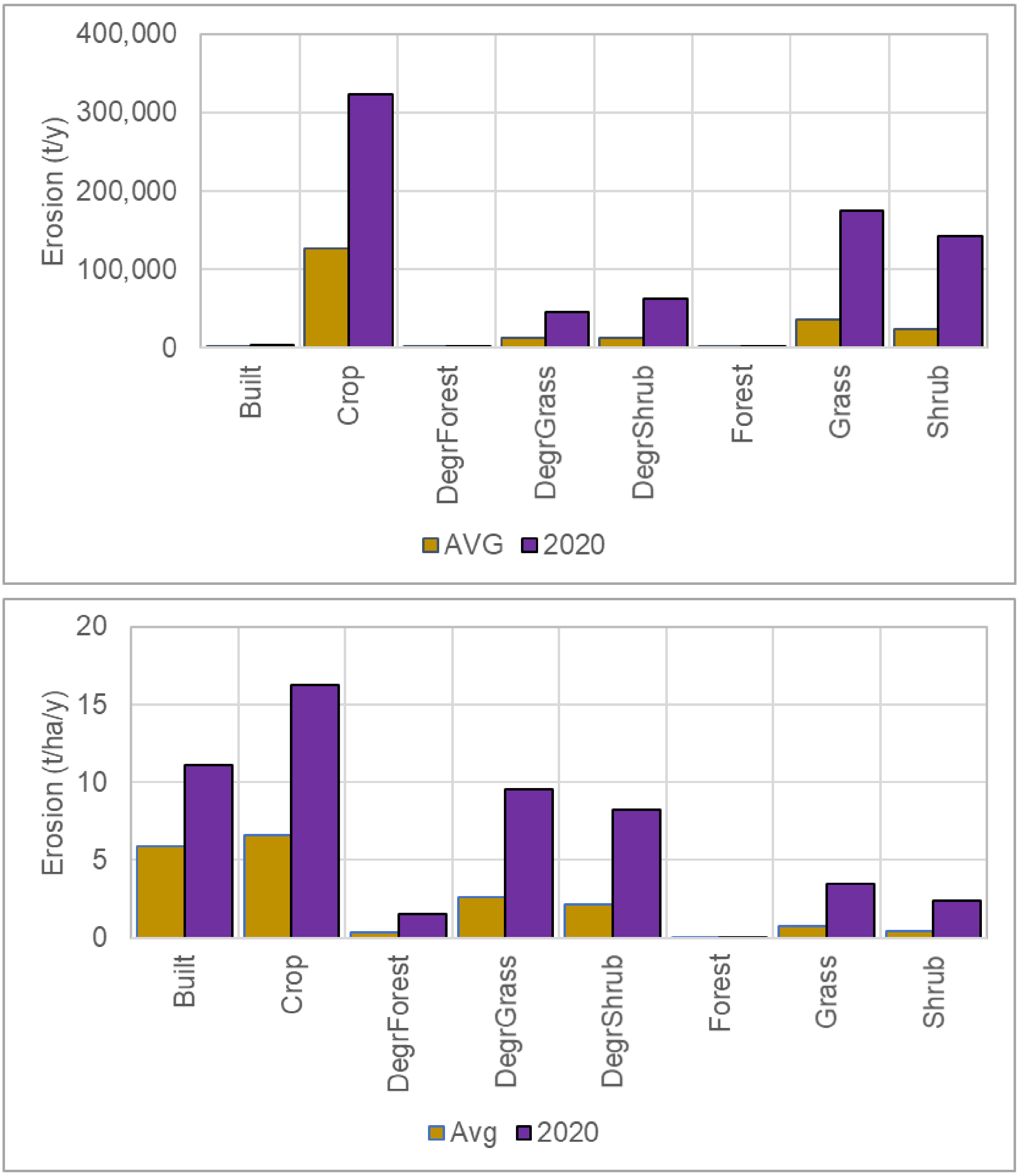


Figure 7-49. Erosion for the main land covers in the Mwache Dam catchment. AVG is the average over 20 years (2001-2020); 2020 is the year with the highest erosion rates. Note that "Built" includes bare soils and roads as well. Top: total erosion generated per land cover; bottom: erosion rates per hectare.

SCENARIO ANALYSIS

Defining scenarios for the Mombasa Water Fund (MWF) have been proven to be challenging as the number of options that might be evaluated is virtually unlimited.

The approach taken here is to start off with a most realistic future, including all projected developments in terms of climate change, economic development, environmental flow requirements, population growth and resulting changes in demands. This approach can be considered as the most likely one and are presented in the following sections. Those scenarios also assume that the actions taken in the context of the MWF will lead to awareness rising and therefore demand and water quality will be altered as well.

However, those integrated scenarios are somewhat less clear in analyzing the actual impact of the MWF catchment actions only, as other factors (climate, demand variation, environmental flows) might obscure the results. In the last section of this chapter results of the scenarios where only MWF catchment actions are considered are presented. The results of those scenarios are also used in the subsequent economic analysis.

The actual MWF actions that will be taken determines which scenario reflects best the projected impact: an all-inclusive MWF including expected impact on stakeholders with associated actions on water demand management and water quality, or a MWF focusing merely on catchment interventions only. Interesting in this regard is the study from 2017[35], co-authored by TNC staff, emphasizing that Water Funds should go beyond the only bio-physical implementation and should include the broader range of potential interventions including stakeholder engagements that might lead to such an all-inclusive Water Fund.

SCENARIO DESCRIPTION

The current situation (without dam and reservoir) has been described in detail in the previous section. That section flagged already quite some issues that requires attention from water managers and policy makers. It provides also solid overview on where and what can be done in terms of the proposed Mombasa Water Fund (MWF).

In this section, we quantify the impacts (positive and negative) of construction of the Mwache Dam, and the impact of a set of interventions (combined in scenarios), using the WEAP model. Four post-dam scenarios were evaluated, as follows:

- Business as usual (do nothing) scenario (00_BaU)
- World Bank interventions scenario – where the planned catchment interventions (covering 2000 ha) have been carried out (01_WB).
- Full interventions scenario – catchment interventions and awareness raising leading to demand management carried out to their maximum extent (02_Full)
- Cost-effective intervention scenario - catchment interventions and awareness leading carried out in priority areas in terms of their likely return on investment (03_Eff)

All scenarios were analyzed for the period 2021 to 2050. Daily weather patterns were assumed to be similar as 2001-2020 (e.g. 2021 and 2041 same as 2001), while climate change has been superimposed on those historic values (see detail hereafter). It was further assumed

[35] Goldstein, J.H., Tallis, H., Cole, A., Schill, S., Martin, E., Heiner, M., Paiz, M.C., Aldous, A., Apse, C., Nickel, B., 2017. Spatial planning for a green economy: National-level hydrologic ecosystem services priority areas for Gabon. PLoS One 12, 1–21. https://doi.org/10.1371/journal.pone.0179008

for the purpose of this simulation, that the Mwache Dam would be completed in 2022 and that the water supply facilities to deliver to Mombasa will be in use in 2025. Most probably the Mwache Reservoir will become online several years later, but this will not have an impact on the outcomes scenario analysis, which is driven by the variability in weather conditions.

Business as Usual scenario (BaU)

The previous chapter describes in detail the current situation defined as the 20 years period (2001-2020), before construction of the Mwache Dam. The Business as Usual (BaU) scenario assumes that the Mwache Dam and upper check dam will be completed on 1 Jan 2021. Other projected socio-economic developments are included as well. However, mitigation options to address adverse effects of dam development and/or improved landscapes and land management are not included. To summarize, the BaU scenario includes:

- The Mwache Dam and reservoir with a capacity of 138.1 MCM
- Loss of the Mwache Reservoir capacity by sedimentation[36] of 1.62 MCM/y
- Water demand for Mombasa (186,000 m^3 d^{-1})
- Irrigation demand in the Kwale county (25,000 m^3 d^{-1})
- Population growth of 2.5% per year[37]
- Economic development of 1.5 % per year[38]
  - water demand per capita in the catchment will increase by 1.5% per year
  - P concentrations in effluent will increase by 1.5% per year
- Climate change:
  - precipitation: no changes
  - temperature: gradually increase up to 2^0C by 2050

World Bank interventions scenario (WB)

As part of the Mwache Multipurpose Dam Project being implemented through Kenya's World Bank-funded Water Security and Climate Resilience Project (KWSCRP-2), allowance has been made for the implementation of conservation interventions for reducing soil erosion in the catchment. The soil-related interventions include afforestation and reforestation activities, constructing terraces and gabions to regenerate vegetation and control erosion, and marking and pegging riparian areas where vegetation needs to regenerate. A target of 2,000 ha was set, to be completed by 2022. Also, other interventions are considered such as formation of WRUAs, development of sub-catchment management plans, WQ monitoring, and communication and training in watershed conservation. Construction of a lower check dam will be included as well. These activities are being executed by the Coast Development Authority (CDA).

The World Bank interventions have been included in the WEAP model using the following parameters and data:

- Sediment inflow in reservoir will be reduced by 0.7 MCM per year (so from 1.62 to 0.92 MCM per year) as a result of the construction of the lower check dam;
- Phosphorous levels do not increase and stay at the base level of 6 mg l^{-1} as a result of the Agriculture Chemical Use Reduction Plan and the Health and Hygiene Plan;

36 The values of the Nippon Kai's estimate were used here for consistency. As shown in the previous section those values correspond to what can be expected in a very wet year.

37 A 2.5% annual growth rate means about doubling in 30 years time ($x = x_0 * 1.025^{30}$)

38 A 1.5% annual growth rate means about 50% increase in 30 years time ($x = x_0 * 1.015^{30}$)

- Environmental flow requirements should be maintained. For each month a percentage of the "natural flow" (=before dam 2001-2020) should be maintained. [39]
- The 2000 ha to be regenerated are assumed to be located in the four most downstream sub-catchment (Mwac, Ngon, Umwa, Chig).

The World Bank interventions scenario formed the baseline against which the two Mombasa Water Fund scenarios were evaluated.

Full and cost-effective intervention scenarios

The Mombasa Water Fund model seeks to blend large-scale natural ("green") infrastructure-based investments and select local livelihood development interventions, potentially with traditional, well-sited, conventional ("grey") infrastructure in a way that, through calculated trade-offs, optimizes delivery of the desired development outcomes while safeguarding vital ecological and socioeconomic attributes and functions. The nature-based solutions that could be implemented through an appropriate combination of incentives, compensation, alternative livelihoods and/or legislation include agricultural and rangeland best management practices, improved forest management, improved protection and restoration. A further and in-depth discussion on those so-called Hydrologic Ecosystem Services (HES) can be found in a recent scientific journal article[40].

Details on the exact location and type of interventions depends on the local physical and socio-economic settings and require therefore field inspection and interaction with local inhabitants. To assess the potential success of those interventions the developed WEAP model has been expanded with those potential interventions. Two scenarios were defined: full interventions (02_Full) and cost-effective interventions (03_Eff). The overall difference is that for the 02_Full it is assumed that land use and management improvements will take place in the entire catchment, while the 03_Eff optimizes in which areas the optimal benefit-cost achievements can be made. The latter is determined using the ROOT model as described in the previous chapter. Other assumptions considered in the two MWF scenarios are:

- Sediment inflow in reservoir will be reduced by a combination of measures: regeneration of degraded lands, land management practices such as terracing, gabions, contour strips, construction of the lower check dam. In summary this will result in a sedimentation rate of 0 MCM/y (02_Full) and 0.46 MCM/y (03_Eff)
- Phosphorous levels in the effluent are assumed to decrease by a series of measures. It is assumed that the effluent concentrations will go down to 1 mg l^{-1} and 3 mg l^{-1} for respectively 02_Full and 03_Eff. Those reductions can be in achieved by grey infrastructure (piped sewerage system and a wastewater treatment plant). Given the low development situation in the area this is a unlikely in the near future so green solutions (reed beds, etc) might be an option.
- Economic growth and population growth will not lead to additional water consumption in the catchment as more productive use of water will be at the same rate as those economic and population growths. Under the 02_Full it is assumed that no increase at

[39] Jan 30%, Feb 30%, Mar 40%, Apr 50%, May 60%, Jun 40%, Jul 30%, Aug 30%, Sep 30%, Oct 30%, Nov 40%, Dec 50%

[40] Goldstein, et al. 2017. Spatial planning for a green economy: National-level hydrologic ecosystem services priority areas for Gabon. PLoS One 12, 1–21. https://doi.org/10.1371/journal.pone.0179008

all will happen; under the 03_Eff it is assumed that some increase will take place by economic development and population growth.

SCENARIO RESULTS

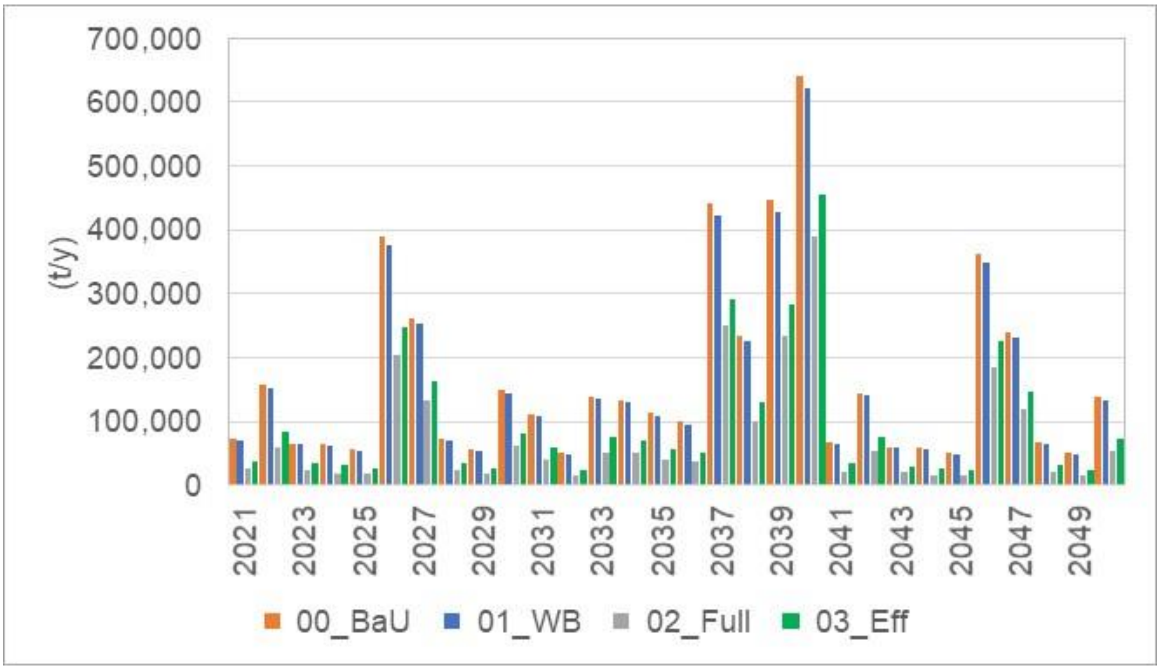
Using the WEAP model, we estimated the impacts of the four scenarios (00_BaU, 01_WB, 02_Full, 03_Eff) on four sets of indicators:

- Erosion
- Water supply and shortages
- Hydrologic Ecosystem Services (HES)
- Reservoir dynamics
- Water quality

Impacts on erosion

The four scenarios were compared in terms of their erosion rates. Figure 7-50 shows the average annual erosion for the four scenarios over the entire catchment. As demonstrated in the previous chapter erosion can vary substantially in space and time. The figure however demonstrates the effectiveness of the different interventions. The WB scenario is able to reduce erosion by only 3 to 4% through the regeneration of some parts of the catchment. However, erosion rates remain high. The MWF interventions reduce erosion quite substantially, such that mean erosion only rises above 1 ton per hectare during wet years.

Figure 7-51 to Figure 7-55 show in which sub-catchments those reductions can be achieved under the scenarios compared to BaU and WB respectively.



	01_WB	02_Full	03_Eff
2026-2035	-3.7%	-56.9%	-43.3%

	01_WB	02_Full	03_Eff
2041-2050	-3.6%	-58.0%	-44.0%

Figure 7-50. Annual average erosion rates in tons per year under the different scenarios. BaU = Business as Usual; WB = World Bank interventions; MWF = Mombasa Water Fund interventions

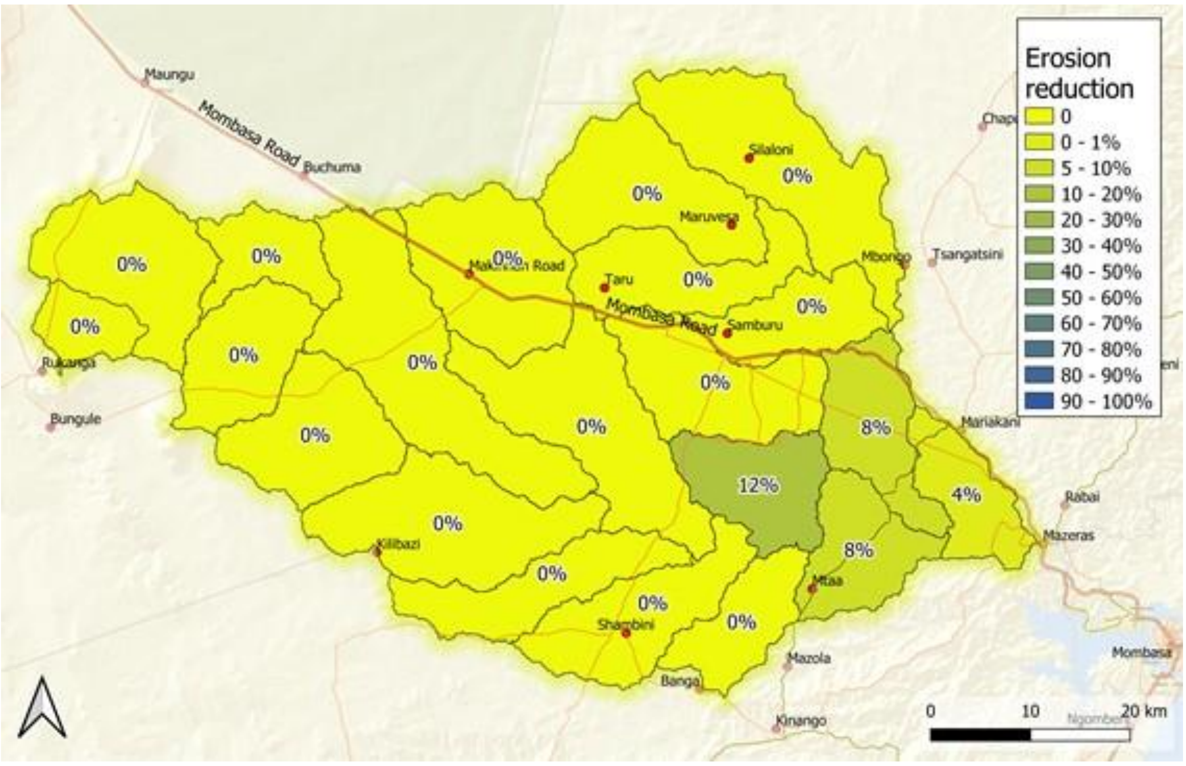


Figure 7-51. Reduction in erosion for each sub-catchment. Percentages present the reduction for the WB scenario ***compared to the BaU****.*

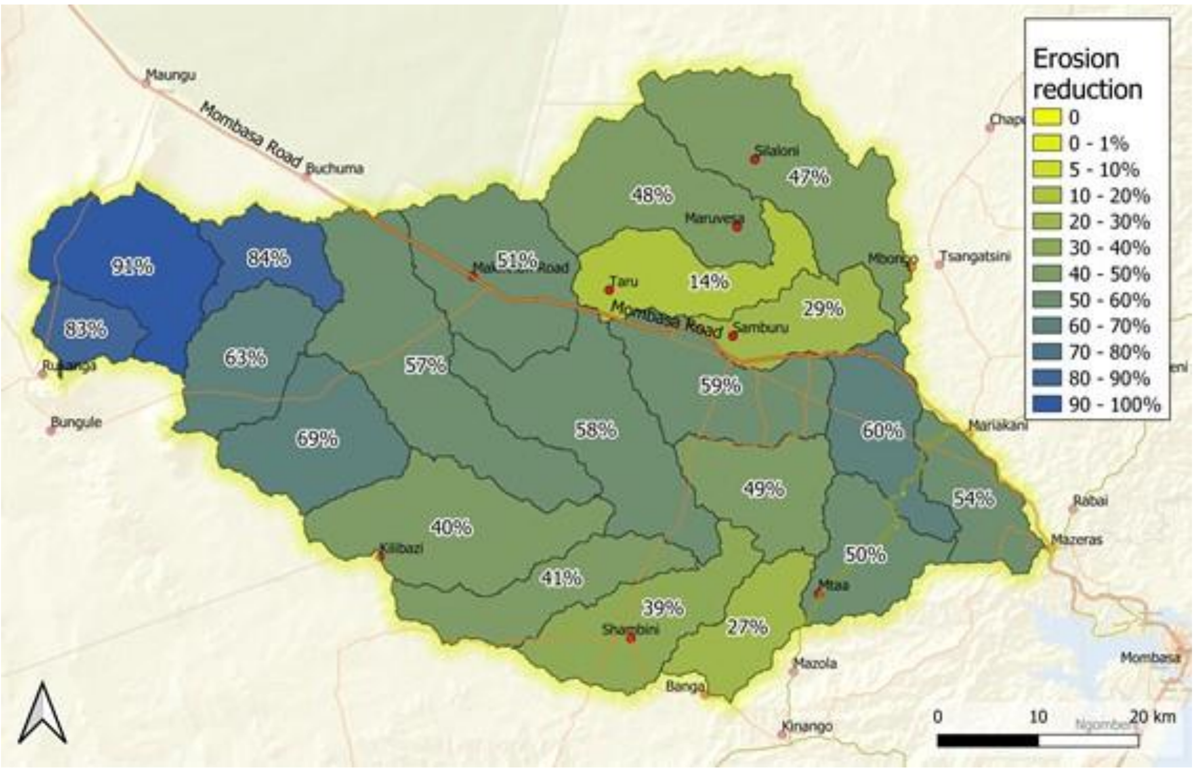


Figure 7-52. Reduction in erosion for each sub-catchment. Percentages present the reduction for the Full scenario ***compared to the BaU****.*

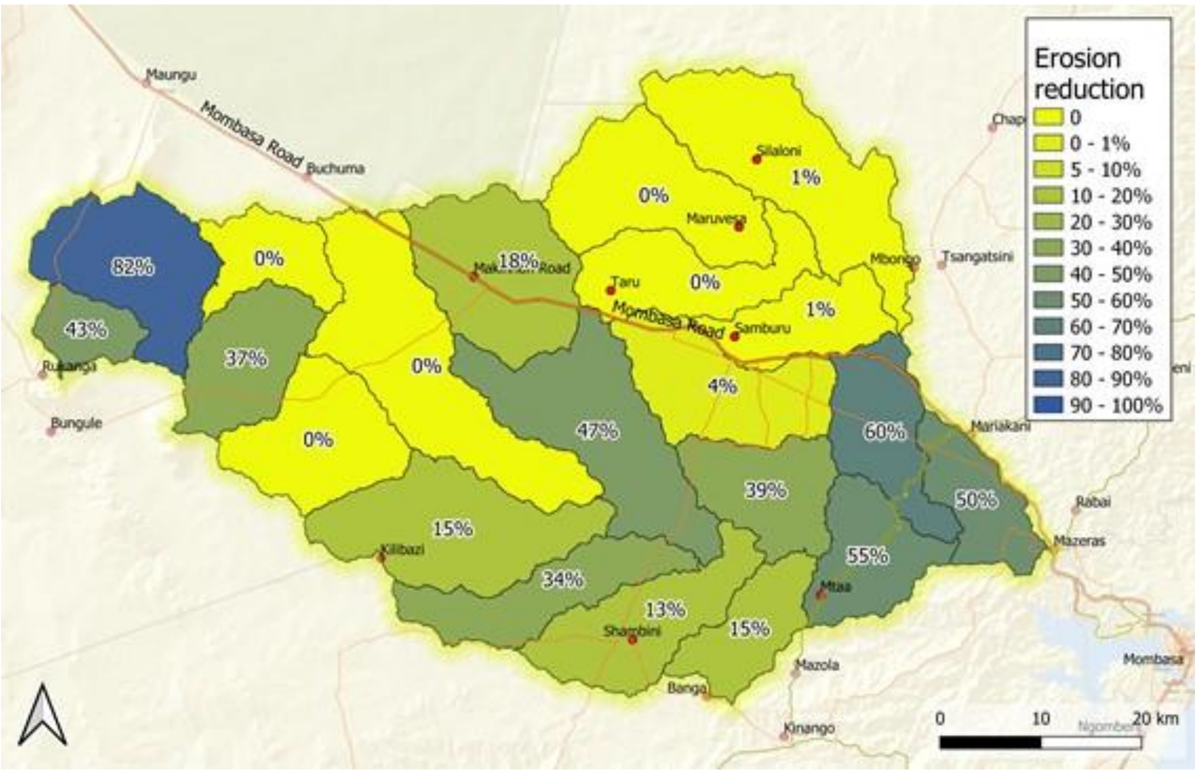


Figure 7-53. Reduction in erosion for each sub-catchment. Percentages present the reduction for the cost-effective scenario ***compared to the BaU****.*

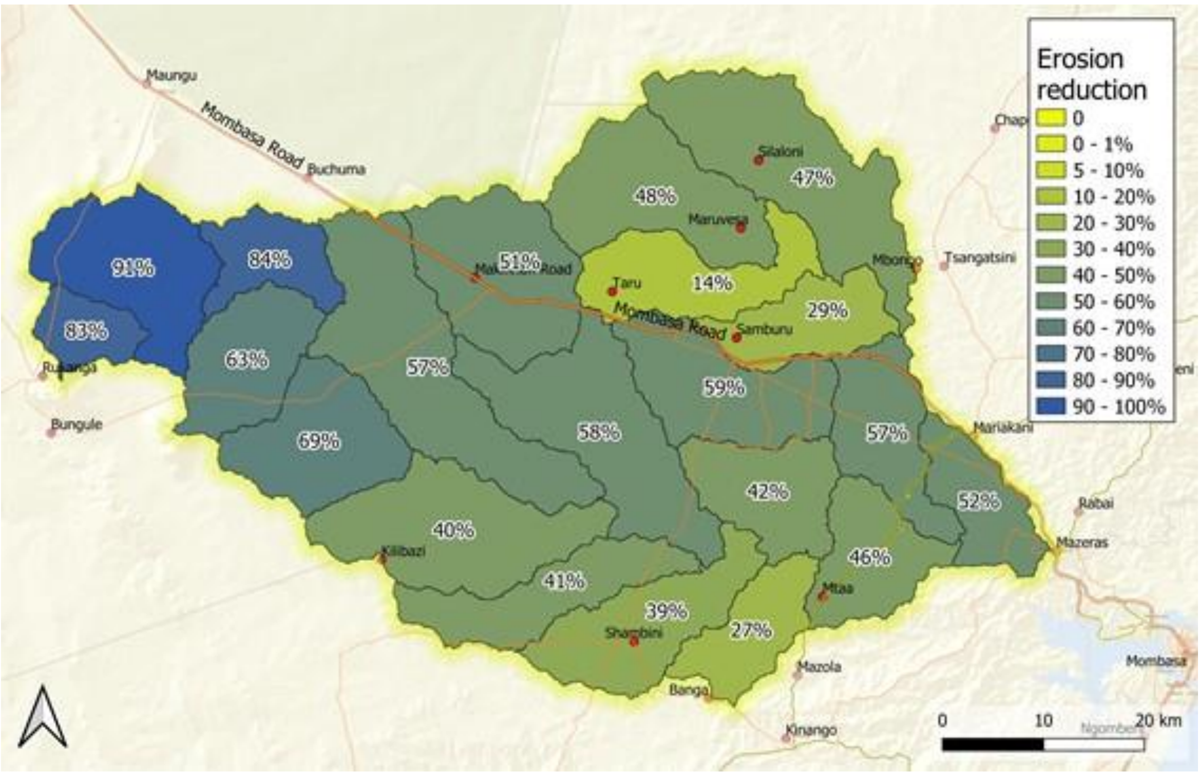


Figure 7-54. Reduction in erosion for each sub-catchment. Percentages present the reduction for the Full scenario ***compared to the WB****.*

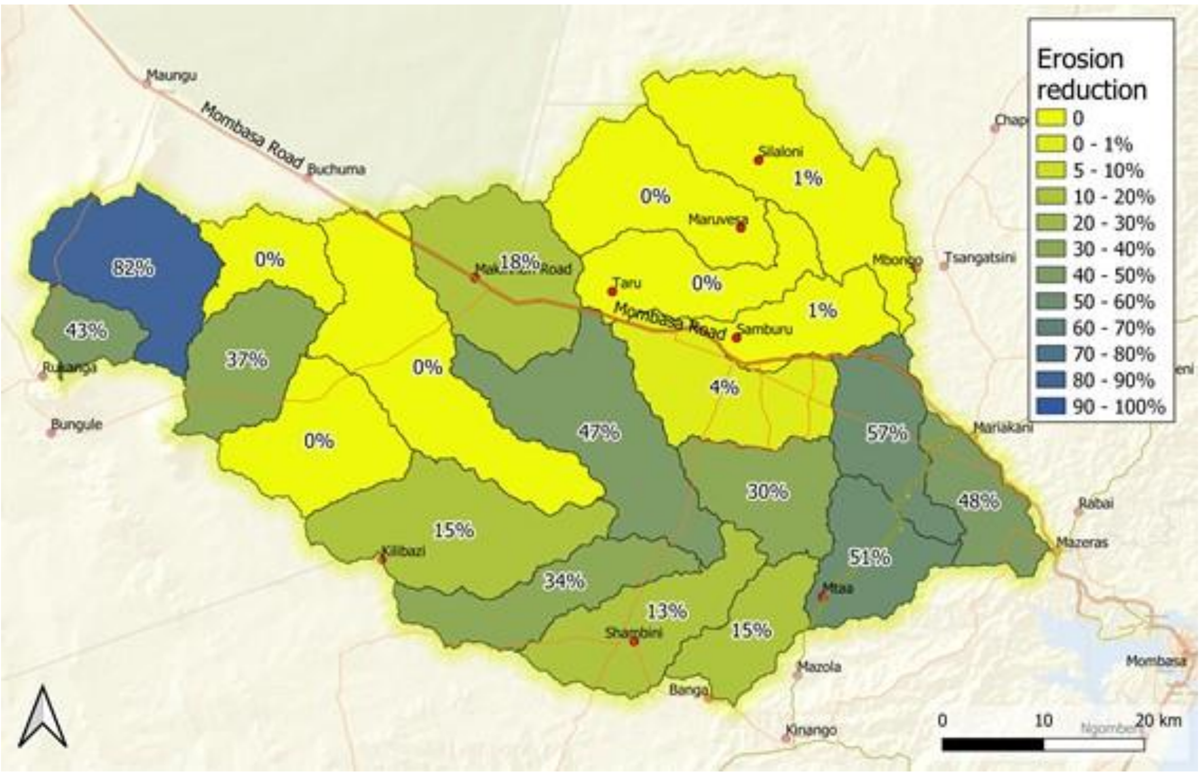


*Figure 7-55. Reduction in erosion for each sub-catchment. Percentages present the reduction for the cost-effective scenario **compared to the WB**.*

Impacts on river flows

The results for daily flows downstream of the reservoir summarized in Figure 7-56. The figure highlights the peak flows and it is clear that under the BaU streamflow up to 250 $m^3 s^{-1}$ can happen in times when the reservoir is full, the soils are wet and additional rainfall is falling. The WB and the MWF are able to reduce those peak flows somewhat, probably making the difference between wide-spread flooding versus manageable high flows. Adaptive reservoir operations are not included in the analysis, but are likely to be able to reduce flooding events.

The derived flow duration curve is shown in Figure 7-57 and details for low (Figure 7-58) flows are presented. Those flow duration curves emphasize again the importance of the various interventions to overcome peak flows and reduce low flow conditions. Figure 7-58 indicates that under all scenarios dry rivers can be expected in around 60% of the days. Under the MWF_Full (02_Full) flows can be maintained in about 70% of the days. Note that no reservoir operational rules were considered and that environmental flows were assumed to have a lower priority compared to Mombasa needs.

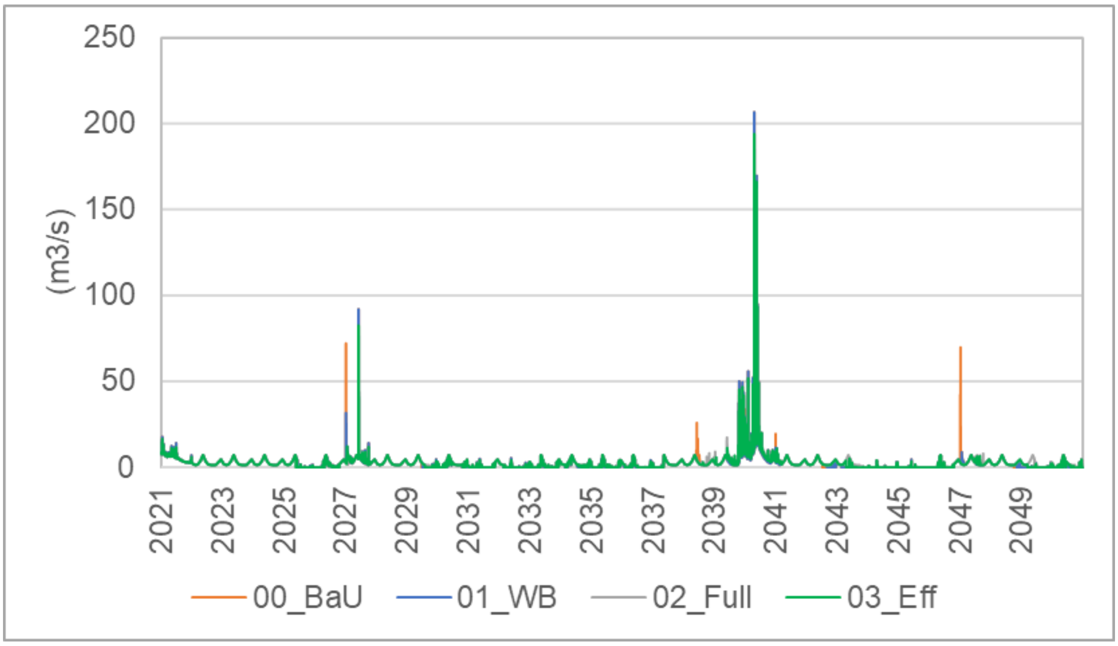


Figure 7-56. Daily streamflow downstream below the new Mwache Reservoir. 00_BaU = Business as Usual; 01_WB = World Bank interventions; 02_Full = Mombasa Water Fund Full interventions. 03_Eff = Mombasa Water Fund cost-effective intervention.

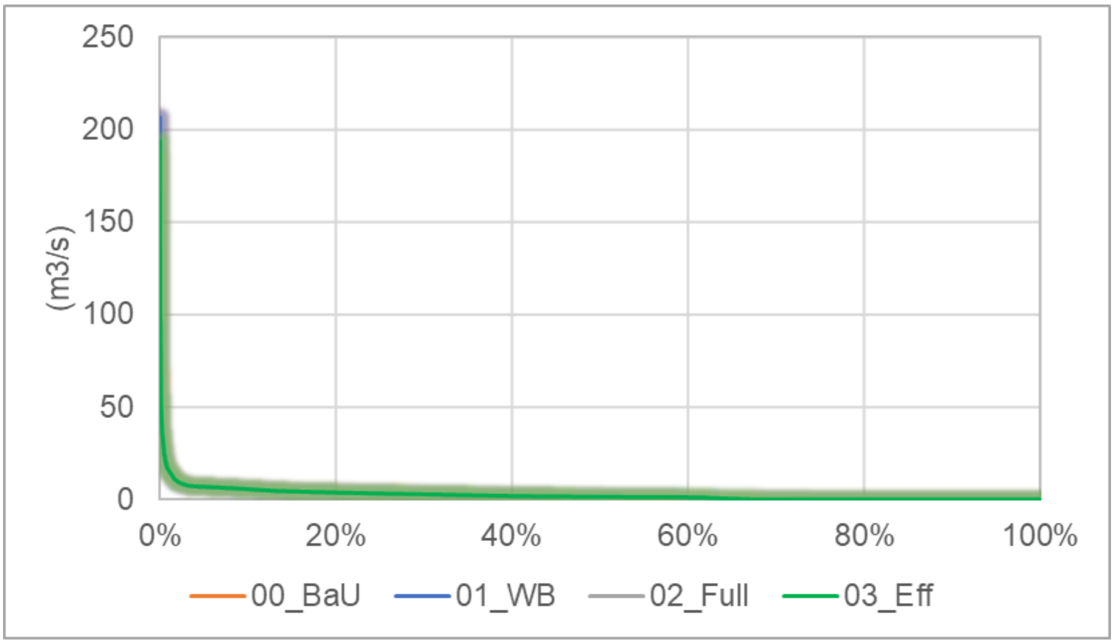


Figure 7-57. Flow duration curve of the daily streamflow downstream of the new Mwache Reservoir.

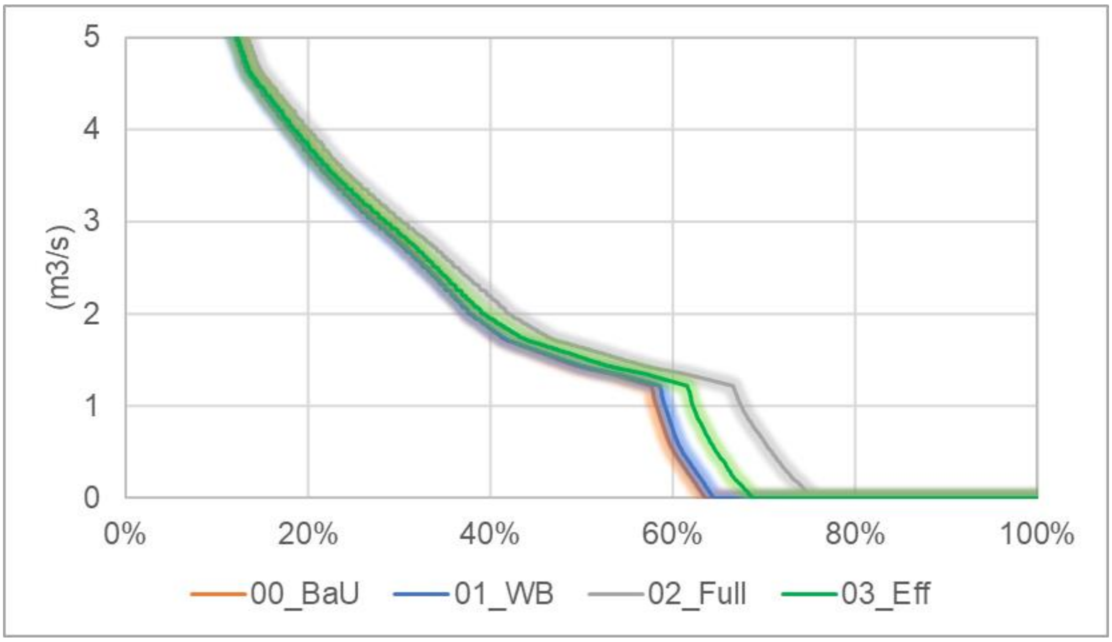
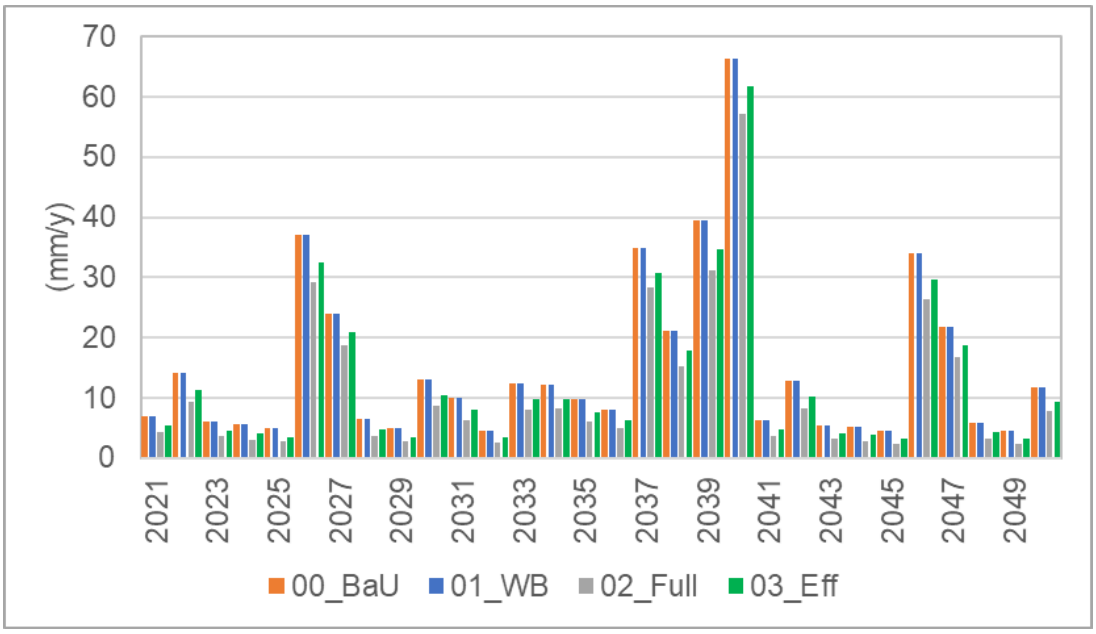


Figure 7-58. Flow duration curve of the daily streamflow downstream of the new Mwache Reservoir. Same data as Figure 7-55 but here focusing on the low flows.

An important component of HES is to understand water dynamics in the catchment. A key component is the division between fast erosive runoff and the slow runoff. The first one is unwanted as it can cause flooding, erosion, peak flows in creeks and rivers etc. By improved catchment management this erosive runoff can be reduced as presented in Figure 7-59. Reductions up to 30% can be achieved under the MWF scenarios.

Figure 7-60 shows the total runoff, water yield, from land into water courses. As found in many other observations and studies regenerating catchments will in general not lead automatically to higher water yields. Regenerated land and soil mean more vegetation that evaporates more water. Also, since fast runoff is reduced more water will infiltrate into the soil and is subsequently available to plants and trees to use during dryer periods. As advocated and demonstrated by others[41] the negative reduction in total water outflow by regenerating catchments is in most cases far outweighed by the gains in other processes (less erosion, more green vegetation, lower flood risks, etc.).

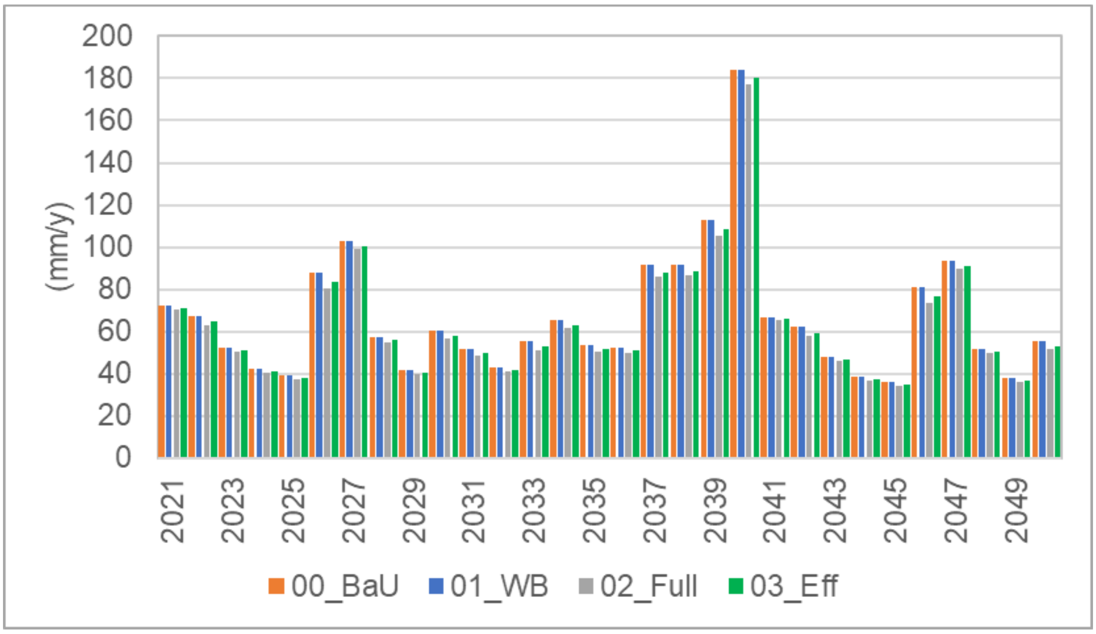
[41] A nice overview article is presented by: Ellison, D., Morris, C.E., Locatelli, B., Sheil, D., Cohen, J., Murdiyarso, D., Gutierrez, V., Noordwijk, M. van, Creed, I.F., Pokorny, J., Gaveau, D., Spracklen, D. V., Tobella, A.B., Ilstedt, U., Teuling, A.J., Gebrehiwot, S.G., Sands, D.C., Muys, B., Verbist, B., Springgay, E., Sugandi, Y., Sullivan, C.A., 2017. Trees, forests and water: Cool insights for a hot world. Glob. Environ. Chang. 43, 51–61. https://doi.org/10.1016/j.gloenvcha.2017.01.002



	01_WB	02_Full	03_Eff
2026-2035	-1.7%	-29.9%	-17.6%

	01_WB	02_Full	03_Eff
2041-2050	-1.8%	-31.3%	-18.5%

Figure 7-59. Erosive runoff in the Mwache Dam catchment. The table indicates changes compared to the Business as Usual scenario



	01_WB	02_Full	03_Eff
2026-2035	-0.4%	-5.7%	-3.6%

	01_WB	02_Full	03_Eff
2041-2050	-0.3%	-5.3%	-3.3%

Figure 7-60. Total runoff (water yield) generated by the Mwache Dam catchment. The table indicates changes compared to the Business as Usual scenario

Reservoir dynamics

The Mwache Reservoir will store water during wet periods in order to supply Mombasa with water year-round. It was assumed that the reservoir would be completed in 2022 and that full supply to Mombasa will start in 2025.

Using a maximum environmental flows assumption, that a complete empty reservoir can be expected in about 50% of the time (Figure 7-61). The reducing reservoir capacity as a result of the sedimentation is also a reason for the different behaviour of those reservoir levels. Sedimentation and therefore loss of storage capacity is noticeable for the BaU and WB scenario. In wetter years less water can be stored resulting in earlier draw-down of the reservoir.

It should be emphasized that no specific reservoir operational rules have been included. All the water demands are instantly delivered as long as the reservoir is not empty. Obviously also the environmental flow requirements contribute to the total demand and are affected by the low reservoir levels in many years.

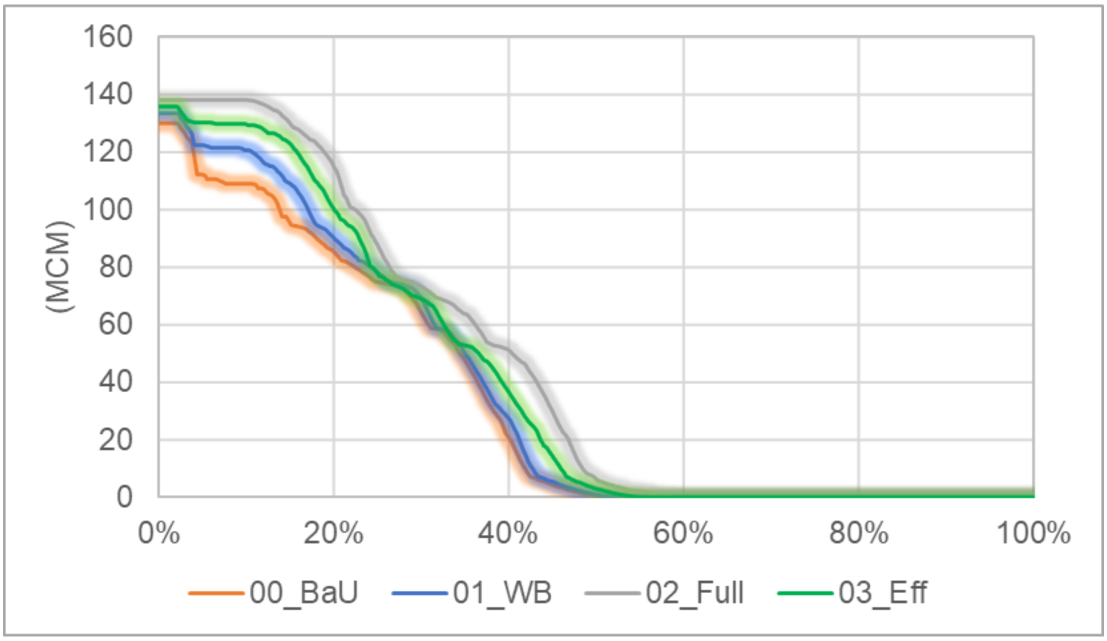


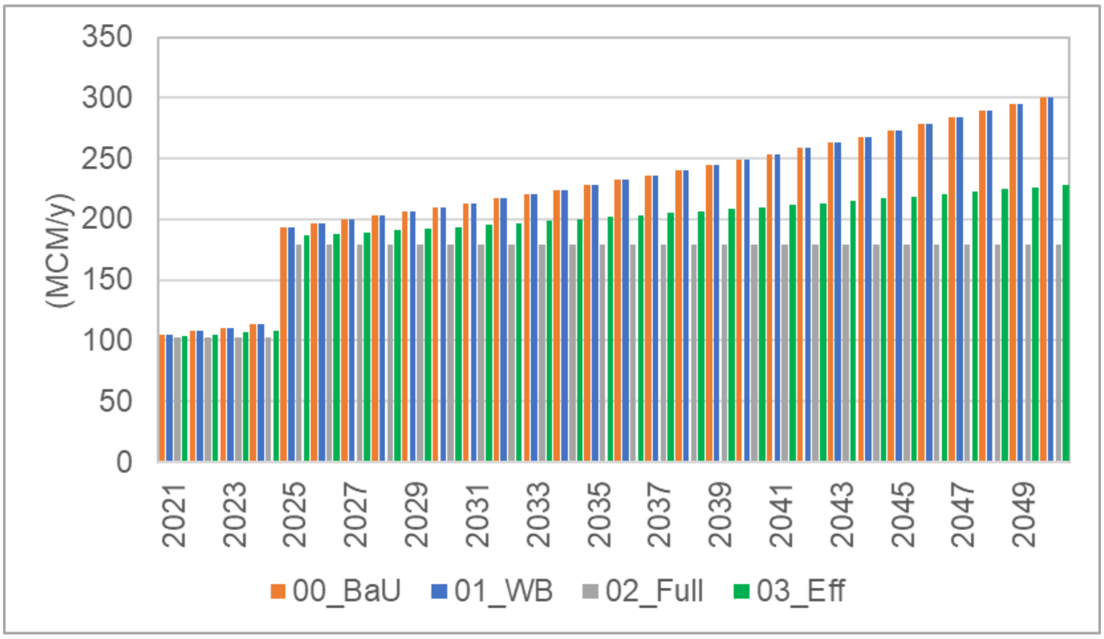
Figure 7-61. Exceedance time of reservoir levels under the different scenarios, under the assumption of a maximum environmental flows allocation.

Water supply and shortages

Water demand will increase under all scenarios by a combination of various factors such as population growth, economic development, climate change, amongst others. Obviously, the most relevant increase in water demand is for Mombasa. Figure 7-62 shows this big jump in demand by 2025 for the Mombasa supply. The gradually increase during the entire 50 years can be attributed to the socio-economic and population developments as well as climate change.

To what extent the catchment can deliver this water demand is shown in Figure 7-63 for all water users and in Figure 7-64 for Mombasa only. The overall trend is that till about 2030 no severe water shortages are projected. Between 2030 and 2040 quite some water shortage might occur. The projected lower water shortage around 2040 can be explained by the wetter conditions around that year. As emphasized earlier, exact rainfall in the future cannot projected and such wet conditions can also happen in earlier or later years.

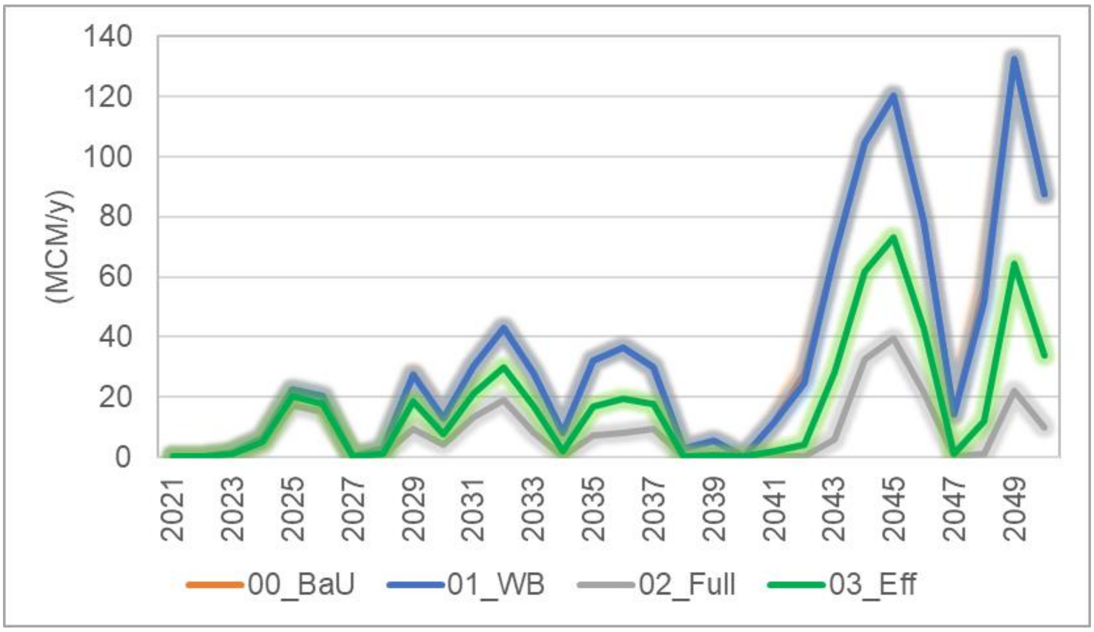
After 2040 water shortage seems to peak and a kind of collapse of the system is projected under the Business as Usual (BaU) and World Bank (WB) scenarios. The Mombasa Water Fund (MWF) interventions as described above are quite effective in reducing water shortages. Overall water shortage is smaller under the MWF scenarios (02_Full and 03_Eff) but during low rainfall years water shortage is still projected.



	01_WB	02_Full	03_Eff
2026-2035	0.0%	-15.2%	-8.1%

	01_WB	02_Full	03_Eff
2041-2050	0.0%	-35.0%	-20.4%

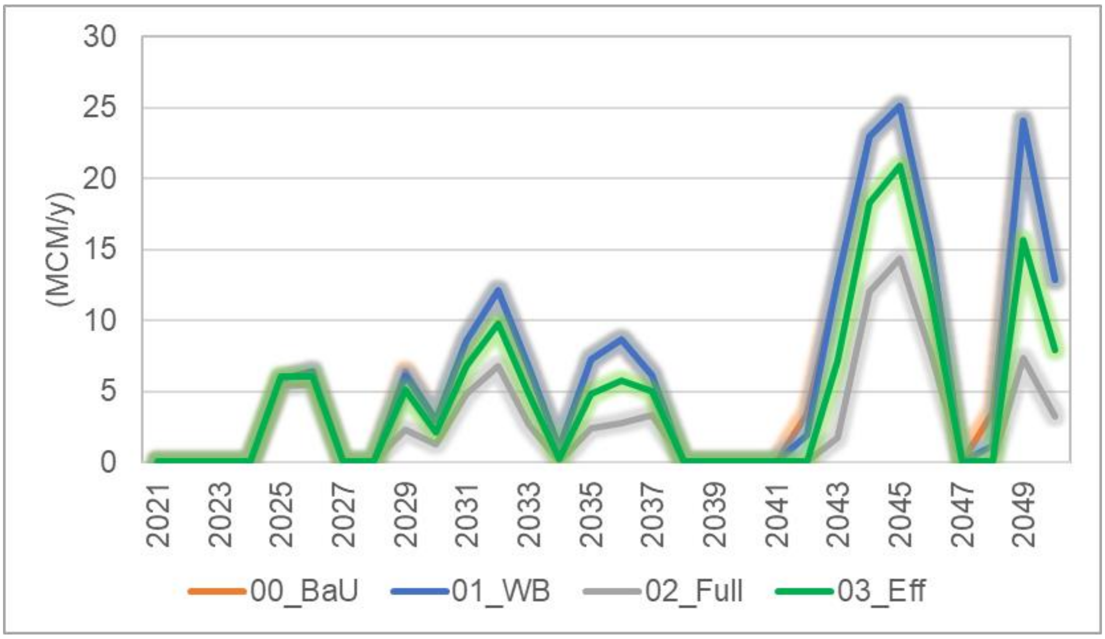
Figure 7-62. Annual water demands for all users in the Mwache Dam catchment including Mombasa. 00_BaU = Business as Usual; 01_WB = World Bank interventions; 02_Full = Mombasa Water Fund Full interventions. 03_Eff = Mombasa Water Fund cost-effective intervention. The Table shows the difference compared to the Business as Usual scenario in percentage for two time horizons.



	01_WB	02_Full	03_Eff
2026-2035	-0.2%	-62.2%	-35.5%

	01_WB	02_Full	03_Eff
2041-2050	-1.2%	-81.0%	-53.8%

Figure 7-63. Annual unmet demand (water shortage) for all water users of the Mwache catchment including Mombasa. Note: 00_BaU and 01_WB overlap nearly completely. 00_BaU = Business as Usual; 01_WB = World Bank interventions; 02_Full = Mombasa Water Fund Full interventions. 03_Eff = Mombasa Water Fund cost-effective intervention. The Table shows the difference compared to the Business as Usual scenario in percentage for two time horizons.



	01_WB	02_Full	03_Eff
2026-2035	0.7%	-50.2%	-22.8%

	01_WB	02_Full	03_Eff
2041-2050	-2.2%	-61.3%	-31.8%

Figure 7-64. Annual unmet demand (water shortage) for Mombasa. Note: 00_BaU and 01_WB overlap nearly completely. The Table shows the difference compared to the Business as Usual scenario in percentage for two time horizons.

Water quality

Water quality was assessed looking at phosphorous loadings and concentrations. Figure 7-65 shows the daily phosphorous concentrations in the Mwache River at the location where it enters the reservoir. Under the BaU scenario concentrations increase from around 1 to 2 mg/l up to 4 to 6 mg/l around 2050. The MWF interventions have the potential to reduce phosphorous levels drastically and keep levels below 2 and 0.5 mg/l respectively.

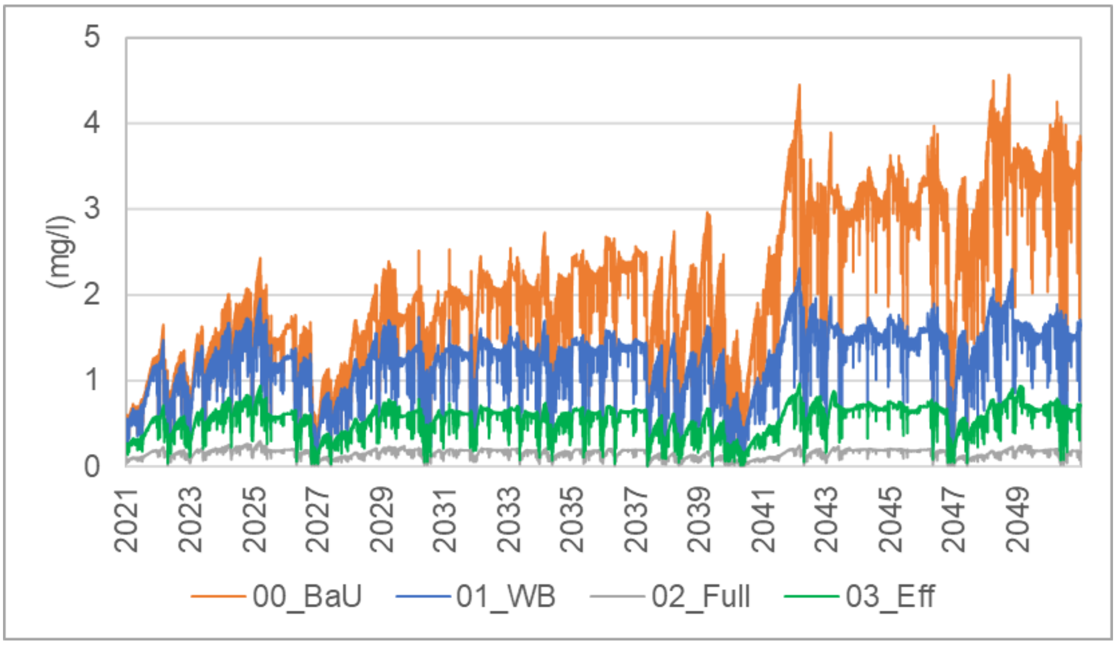


Figure 7-65. River water quality expressed as daily phosphorous concentration entering the Mwache Reservoir under the different scenarios.

Another water quality component analyzed is the total suspended solids (TSS). This is relevant in terms of drinking water treatment plants. Various threshold values are used, like the EPA ones that sets maximum of 500 mg/l[42]. Removal of sediments in drinking water treatment facilities can be quite expensive as large amount of chemicals used for coagulation-flocculation (often alum and iron) have to be used. Daily concentrations of suspended material can go up to 4 g/l.

The exceedance graph indicates that levels of 0.5 g/l or above occur in about 30% of the days for the BaU and WB scenarios, while for the two MWF scenarios this happens only in about 10% of the days.

[42] https://www.epa.gov/sdwa/secondary-drinking-water-standards-guidance-nuisance-chemicals

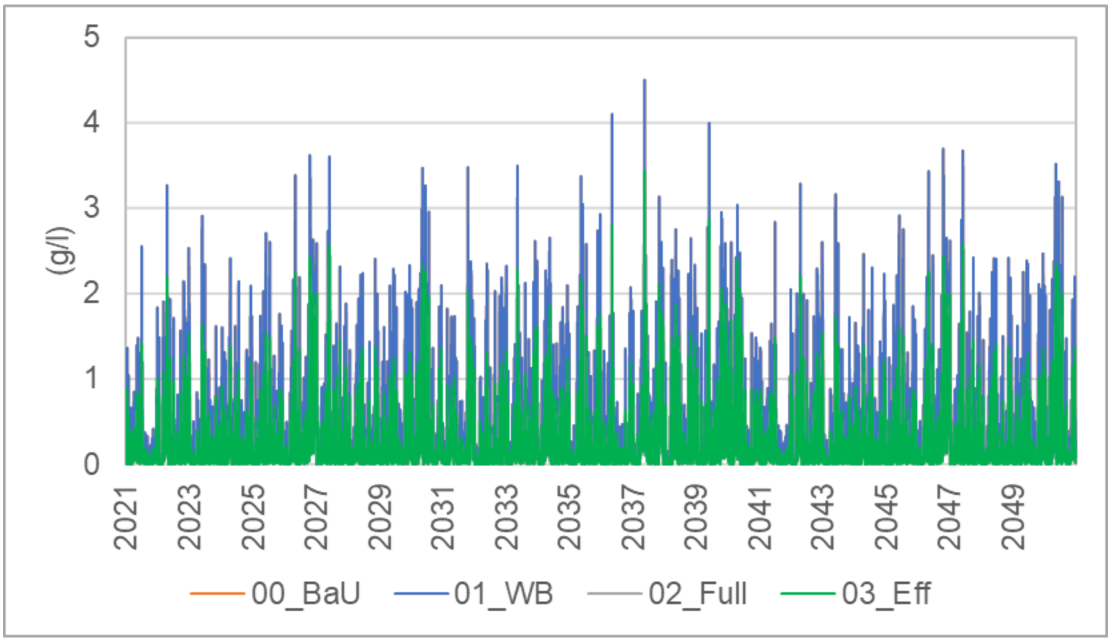


Figure 7-66. Daily concentrations of suspended material originating from erosion in the river just upstream of the Mwache Reservoir under the different scenarios.

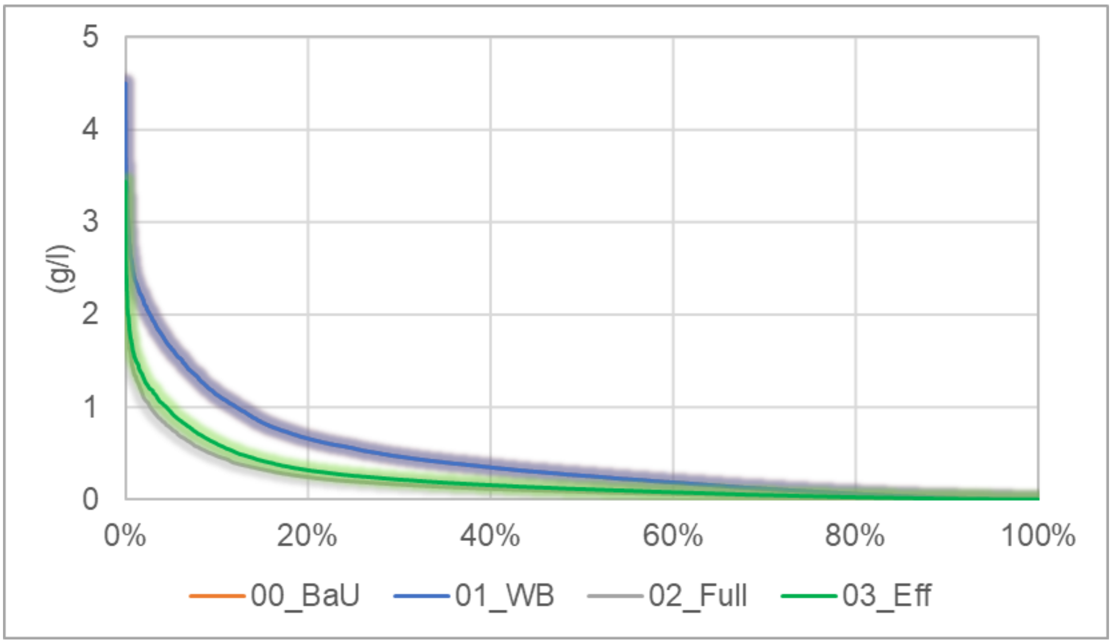


Figure 7-67. Same as Figure 7-66 but expressed as exceedance levels. Nota that 00_BaU and 01_WB are overlapping.

MZIMA SPRINGS SCENARIO

The Mzima springs are expected to deliver 105,000 $m^3 d^{-1}$. It remains however unclear whether this can be sustained in the future. It is therefore interesting to evaluate the impact in case Mzima springs cannot deliver this amount. A scenario has been evaluated where it was assumed that Mizma delivers only 50% of this 105,000 m^3 d^{-1} and that the other 52,500 m^3 d^{-1} by the Mwache Dam catchment. This scenario (04_Mzima) was evaluated using the WEAP model as presented above.

Three other scenarios related to this Mzima springs are added to explore how this additional water from Mwache Dam can be delivered. As presented in the previous section the environmental flow requirements are quite high with values between 30% and 60% (depending on the month) of the natural flows.

In summary the following four scenarios were evaluated based on the Mombasa Water Fund cost-effective scenario (03_Eff) with the WEAP model:

- 04_Mzima: Additional demand of 50% 105,000 m^3 d^{-1} to be delivered
- 05_Mzima_F1: reduce environmental flow requirements by 50%
- 06_Mzima_F2: reduce environmental flow requirements by 75%
- 07_Mzima_F3: reduce environmental flow requirements to a fixed amount of 0.5 m^3 s^{-1}

Figure 7-68 shows that water shortage (unmet demand) for Mombasa is expected to roughly double during dry years if Mzima springs deliver only 50% of what is projected. During dry years this unmet demand can increase from about 20 MCM per year to 40 MCM per year (2045).

The three adaptation scenarios for which it was tested whether lower environmental flow requirements might mitigate this water shortage, were evaluated with the WEAP model as well. From Figure 7-69 it is clear that by setting those environmental flow requirements at a fixed value of 0.5 m^3s^{-1} (07_Mzima_F3) water shortage can be reduced substantially, but with much greater risk to downstream ecosystems. Only during very dry years (e.g. 2045) water shortage remains a big issue. Figure 7-70 shows the daily reservoir levels for those scenarios indicate that reservoir levels remain at reasonable levels under this scenario.

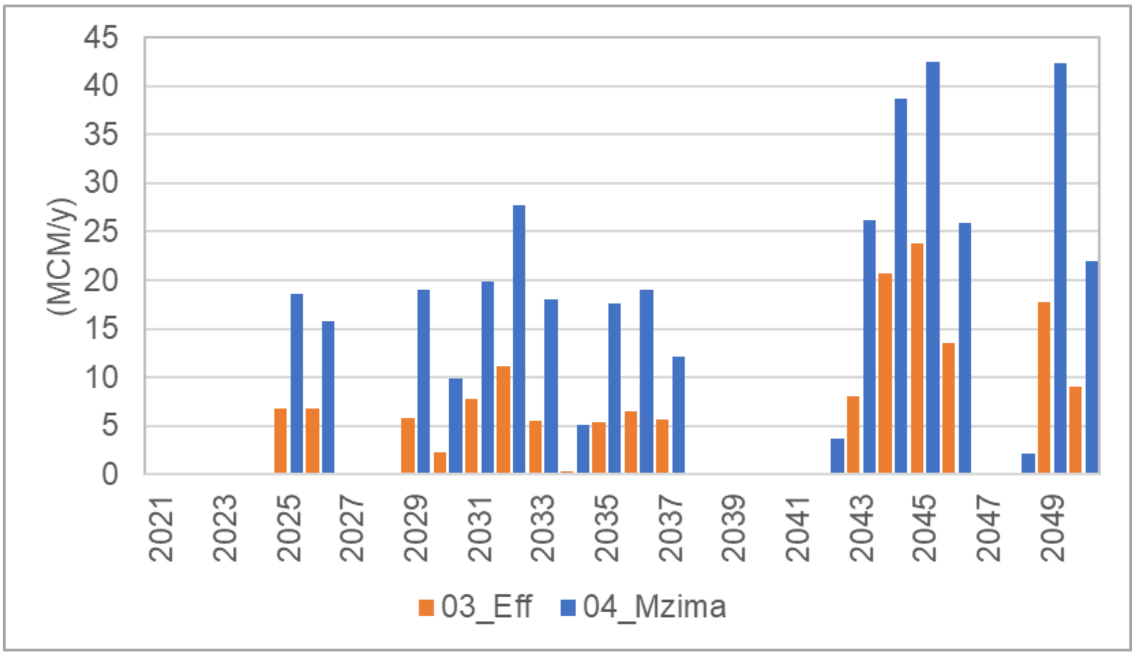


Figure 7-68. Annual water shortage for Mombasa if Mzima springs deliver only 50% of expected.

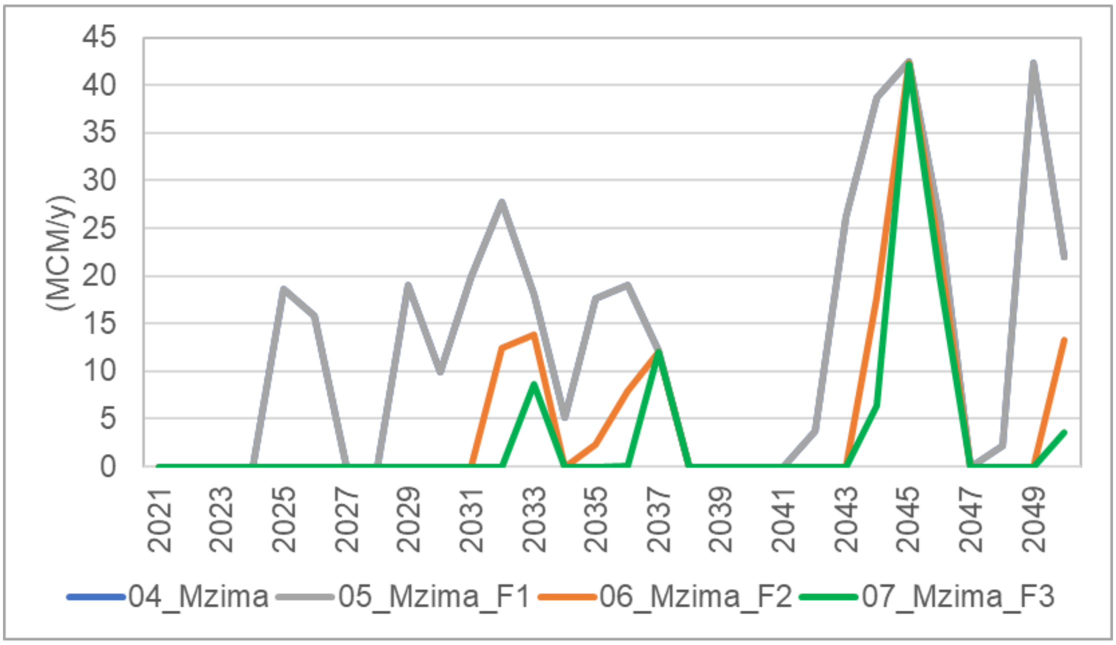


Figure 7-69. Annual water shortage for Mombasa if Mzima springs deliver only 50% of expected (04_Mzima) and three scenarios when environmental flow requirements are reduced. Note that (04_Mzima) and (05_Mzima_F1) are nearly overlapping.

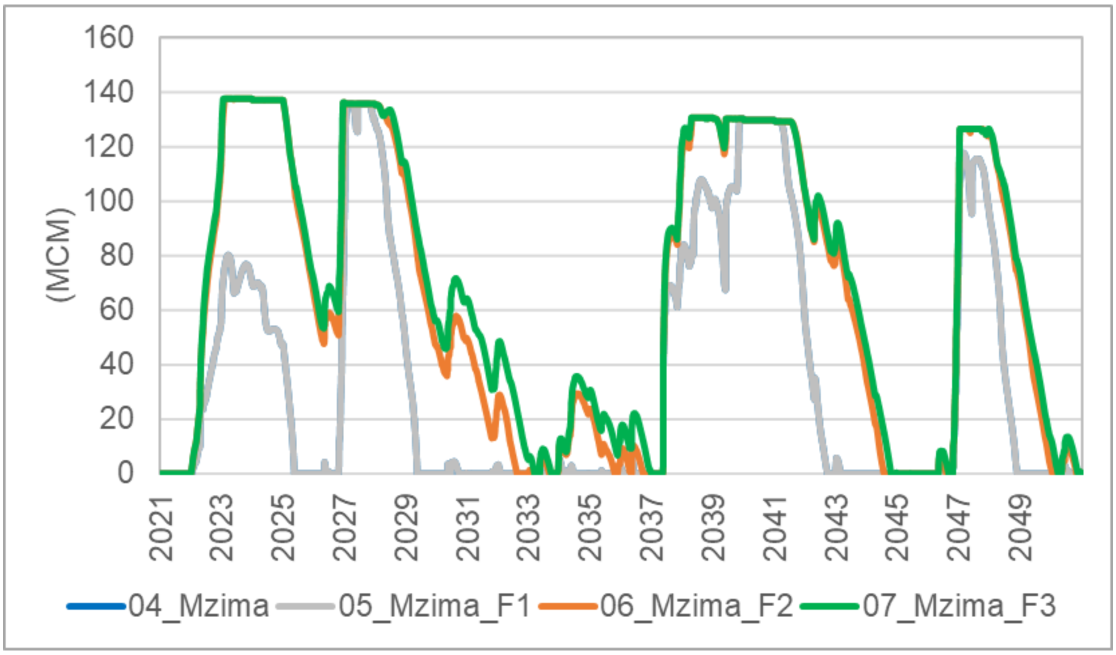


Figure 7-70. Daily reservoir levels if Mzima springs deliver only 50% of expected (04_Mzima) and three scenarios when environmental flow requirements are reduced. Note that (04_Mzima) and (05_Mzima_F1) are nearly overlapping.

SCENARIOS FOR SYSTEM YIELD

The previous sections provide a quite detailed analysis of the results of multiple scenarios under various boundary conditions. Those scenarios included also assumptions on changes in water demand and environmental flow requirements. The rationale behind those intervention scenarios is that by developing the Mombasa Water Fund (MWF) additional awareness rising amongst all concerned would take place as well. Therefore, water demand management measures and water quality improvements would be implemented over time as well. As mentioned earlier such an all-inclusive approach has been advocated by TNC[43].

To explore the impact of the bio-physical component of MWF only a more aggregated and straightforward approach of those scenarios is needed. The results from those scenarios as presented in the previous sections have therefore been altered and constant demands over time were assumed.

To support the economic analysis also a No Reservoir scenario was added.

Assumptions:

- Constant demand for Mombasa of 186,000 $m^3\ d^{-1}$ (= 2.153 $m^3\ s^{-1}$ = 67.9 MCM y^{-1})
- Constant demand for Kwale irrigation of 25,000 $m^3\ d^{-1}$ (= 0.289 $m^3\ s^{-1}$ = 9.1 MCM y^{-1})
- Constant environmental flow requirements of 0.5 $m^3\ s^{-1}$ (= 15.8 MCM y^{-1})
- Initial reservoir capacity of 138.1 MCM
- Reduction of reservoir capacity varies per scenario
  - 00_BaU: 1.62 MCM y^{-1}
  - 01_WB: 0.92 MCM y^{-1}
  - 02_Full: 0.00 MCM y^{-1}
  - 03_Eff: 0.46 MCM y^{-1}
  - 05_NoRes: N/A

RESULTS

The outputs of the scenario analysis for water yield from the dam suggest that the impact of the MWF interventions will be modest. This likely reflects the compensatory effects of reduced sediment accumulation on the one hand and reduced runoff on the other. Under the BaU scenario, the dam yields the planned supply of 186 000 m^3/day to Mombasa and 25 000 m^3/day to Kwale around 96% of the time between the time of construction and 2050 (Figure 7-72 and Figure 7-73). Under the WB scenario, the planned supply can be sustained around

[43] Goldstein, J.H., Tallis, H., Cole, A., Schill, S., Martin, E., Heiner, M., Paiz, M.C., Aldous, A., Apse, C., Nickel, B., 2017. Spatial planning for a green economy: National-level hydrologic ecosystem services priority areas for Gabon. PLoS One 12, 1–21. https://doi.org/10.1371/journal.pone.0179008

96.5% of the time, while this increases further to just under 99% under the MWF_cost-effective scenario. Notably, the model suggests the dam will be able to provide the planned supply allocation virtually 100% of the time under the MWF_Full scenario.

In terms of average daily yields from the dam between the time of reservoir completion and 2050, the MWF_Full extent scenario increased average daily yields by 1.6% compared to the BAU scenario. Average daily yield under the MWF_Full scenario is 210 900 m^3/day, reflecting the fact that the dam is able to supply the full 211 000 m^3/day (*i.e.* 186 000m^3/day for Mombasa plus 25 000 m^3/day for Kwale) almost 100% of the time. Under the BaU scenario, average daily yield drops to 207 500 m^3/day, highlighting that the dam will not always be able to sustain the planned demand of 211 000 m^3/day. With an average daily yield estimate of 209 800 m^3/day, the Mombasa_Eff scenario increases average daily yield by 1.1% impact compared to the BaU scenario. Finally, at 207 800 m^3/day, average daily yield under the WB scenario is just 0.15% higher than under the BaU scenario.

Overall, the modest impact of the MWF interventions on water yields from the dam suggests the main hydrological benefits of the proposed activities will be reduced costs of clearing sediments from the check dams and reduced water treatments costs due to lower levels of suspended solids.

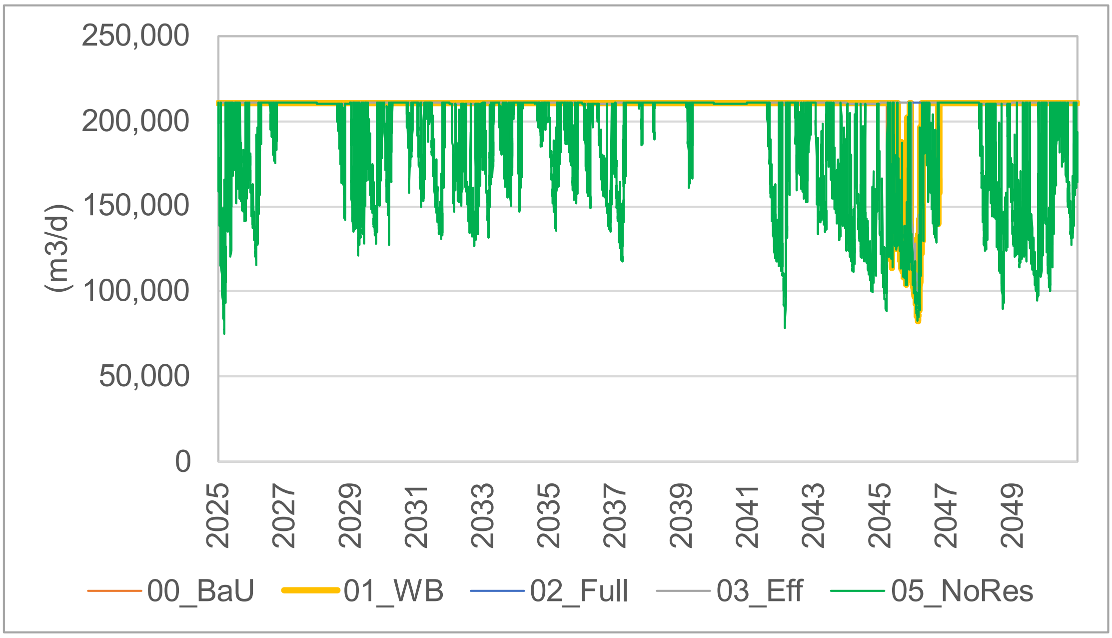


Figure 7-71. Daily water delivered to Mombasa and Kwale irrigation system for the four scenarios.

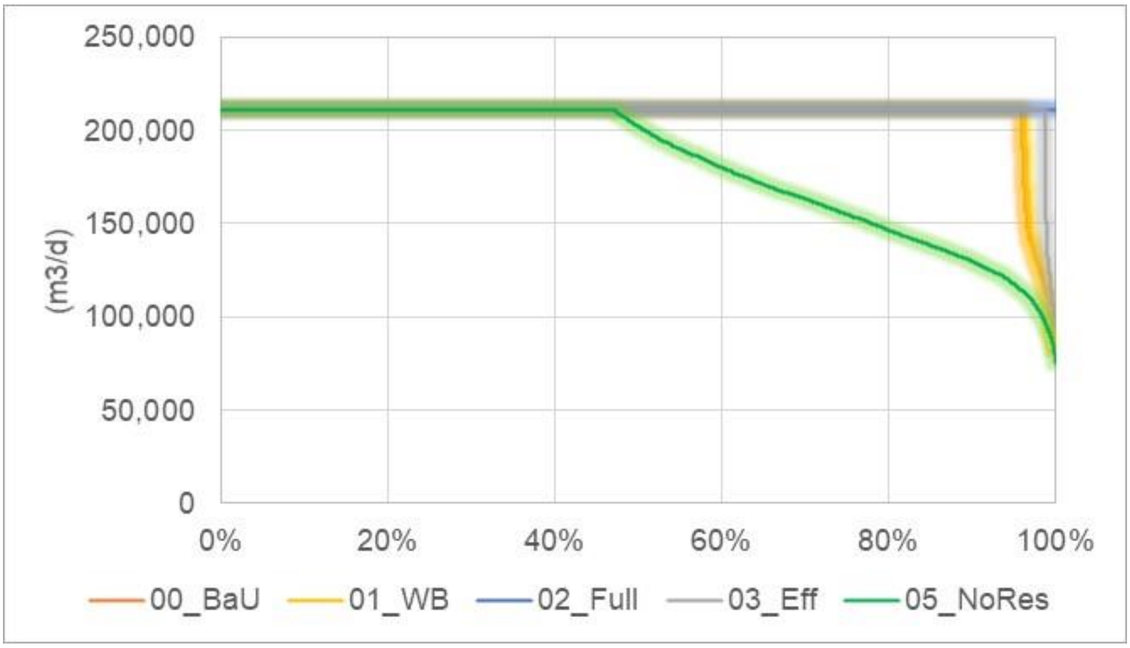


Figure 7-72. Same as Figure 7-71, plotted as exceedance levels.

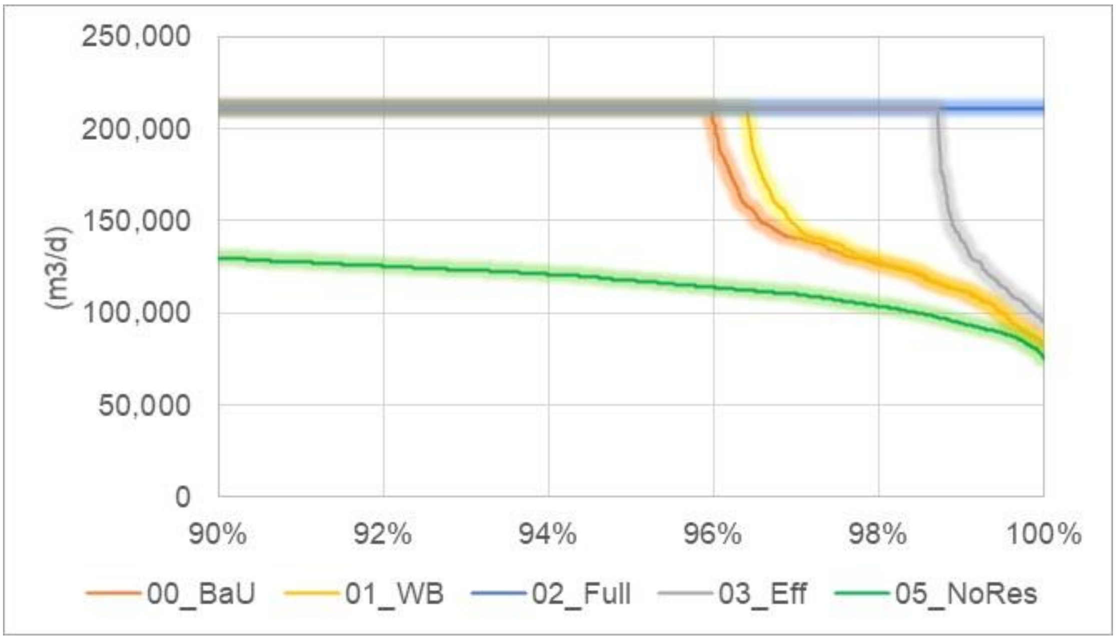


Figure 7-73. Same as Figure 7-72, x-axis plotted between 90% and 100%.

8 ECONOMIC ANALYSIS

OVERVIEW

The focus of the Mombasa Water Fund is to secure water resources to Mombasa and Kwale counties while at the same time safeguarding biodiversity and improving the health and wellbeing of local communities. The Water Fund seeks to achieve this through implementing catchment conservation activities to improve water yields, reduce soil erosion, protect biodiversity and improve livelihoods. The suite of interventions proposed to address the main threats to Mombasa's water security and the methods for determining their extent and spatial allocation have been described in detail earlier in the report. Here we provide a brief recap of the selected interventions, their proposed extent and associated estimated costs.

SUMMARY OF INTERVENTION COSTS

MWACHE DAM CATCHMENT AREA

The proposed extent and cost of conservation interventions in the Mwache Dam catchment are summarized below. The selected priority areas for intervention have a total establishment cost of US$6.2 million and ongoing costs of US$2.2 million per year (Table 8-1). The total cost is estimated to be US$32.9 million in present value terms for priority intervention.

Table 8-1. Total extent and costs of proposed interventions

Intervention	Extent (ha)	Establishment / setup cost (US$)	Ongoing cost (US$/y)
SEC1 on cultivated land	4 768	715 000	191 000
SEC2 on cultivated land	4 727	1 182 000	307 000
SEC3 on cultivated land	2 888	1 444 000	231 000
Sustainable resource management	4 402	2 131 000	319 000
Active rehabilitation (non-riparian areas)	383	383 000	57 000
Riparian rehabilitation	200	260 000	39 000
Riparian protection	5 944	9 000	253 000
Community conservation areas	19 881	30 000	845 000
Total costs		**6 153 000**	**2 242 000**

MZIMA SPRINGS RECHARGE AREA

Implementation of a PES scheme in the Chyulu Hills area was estimated to involve establishment costs of US$2 million and ongoing costs of approximately US$6.3 million per year (see Chapter 6) or US$72 million in present value terms.

WATER SECURITY BENEFITS

Upstream catchment areas in the counties of Kwale, Taita-Taveta and Kilifi are serving ecosystems and communities downstream in Mombasa. The activities that take place upstream can have a significant and lasting impact on ecosystem goods and services that are generated downstream. Various stakeholder groups benefit from these ecosystem services, which include the water supply benefits associated with hydrologically-linked catchment services. These are measured in terms of their impacts on water yield, sediments and raw water quality. The impacts on water yield are estimated for both the Mwache Dam catchment and for the Mzima Springs Recharge Area where the forests of Chyulu Hills play an important role in supplying water to the Chyulu Hills Aquifer which feeds the springs. For these estimates we rely on the modelling work undertaken as part of the GNIplus study (GNIplus, 2021a). What is not included here is the loss in dry season flow for perennial rivers that are supplied by the Mzima Springs and the households that are directly dependent on surface water as their main source of drinking and cleaning water. The impacts on raw water quality are assessed in terms of water treatment cost savings associated with the proposed water treatment plant to be developed alongside the Mwache Dam.

IMPACTS ON SEDIMENTS

Modelling carried out using the InVEST TDR tool suggests that the proposed Mwache Dam catchment interventions could reduce sediment export by at least 16% relative to the business-as-usual (BAU) situation. A major benefit of this would be the reduction in the costs of sediment clearing from check dams. Based on the estimated sedimentation rates and annual costs of sediment clearing from the check dams in the design report, this suggests that the proposed soil conservation measures could save approximately US$1.23 million per year in bulk water supply system management costs.

IMPACTS ON WATER YIELD

Yield and quality of water in a system is largely a function of climatic factors (e.g., rainfall) and land-use patterns in the catchment areas. Indeed, land use change affects water yield and streamflow characteristics by altering hydrological processes through changes in evapotranspiration and soil moisture dynamics (Zhang *et al.*, 2018). Quantifying the effect of land use change on water yields is complex, particularly in the case of forests and their impact on groundwater recharge.

The WEAP model was used to estimate how changes in land use could impact on the availability of water supplies to Mombasa. The impact of future scenarios on water supplies at the Mzima Springs was based on the results from the WaterWorld hydrological model (see (GNIplus, 2021a).

Mwache Dam catchment

The multi-purpose Mwache Dam has the potential to supply 220 000 m^3/d, with approximately 80% of this (186 000 m^3/d) being used to augment water supplies to Mombasa by 2035. It is expected that the potential supply will be 95 585 m^3/d from year one post construction of the dam[44], increasing to 102 859 m^3/d in 2025 and 186 000 m^3/d from 2030 (GNIplus, 2021a).

The Water Evaluation and Planning (WEAP) hydrological modelling tool was used to estimate how the conservation measures would impact the yield of the Mwache Dam, taking into account changes in flows in the catchment and the residual sedimentation of the Mwache Dam (which is not entirely protected by check dams). This suggested that yield would increase by 1.1% relative to the BAU scenario. In other words, yield will decline more slowly over time,

---

[44] The construction contract was only awarded in 2019 and reports suggest that construction will begin sometime in early 2022.

saving on having to make up this difference from the next best alternative, which is likely desalination.

Desalination has become much more efficient and cost-effective in recent years thanks to advances in technology, reductions in costs and energy use, increase in plant size and more competitive project delivery (World Bank, 2019). Indeed, costs (including capital) have been reduced to as low as US$0.50 per m^3 of desalinated water in some parts of the world, with the general cost range now falling between US$0.60-1.80 depending on the size of the plant and the type of technology used (as well as site specific conditions, World Bank, 2019). Further large cost reductions are expected with the World Bank (2019) reporting declines of up to two-thirds over the next two decades. Within 5 years it is expected that the cost of water through desalination will range from US$0.6-1.0 and that in 20 years it will be as low as US$0.3-0.5 (World Bank, 2019). Based on this information, we assume that the cost of desalination in Kenya will follow these trends but have used a conservative unit cost of US$1 per m^3 to cost the additional water needed to cover the respective deficits under future scenarios. Locally, the costs would have to incorporate local electricity prices and the infrastructure requirements to link into the grid.

Thus, the interventions could result in additional water supply cost savings of US$0.75 million per year by 2030.

Mzima Springs

Water supply through abstraction from Mzima Springs is expected to reach 105 000 m^3/d by replacing the existing pipeline with a higher-capacity intake and pipeline by 2030. Approximately 35 000 m^3/d of this will feed the smaller towns of Voi/Maungu, Mwatate and Wudanyi, and 54 000 m^3/d will be supplied to Mombasa (GNIplus, 2021a). This equates to 12.8 million m^3/y and 19.7 million m^3/y, respectively.

Interventions in Mzima Springs recharge area are expected to avoid the reduction in yield from the springs, saving on grey infrastructure costs needed to make up the shortfall. Estimating the benefit of reducing deforestation and degradation was based on hydrological modelling using WaterWorld and an accompanying risk assessment carried out for a recent feasibility study for implementing payments for hydrological services in the Chyulu Hills area (GNIplus 2021) which considered how change in land use and management in the Mzima Spring recharge area might affect water supply at the spring. The study found that several risk factors have a high likelihood of occurrence and could have severe and unmitigable impacts on water supply if deforestation of the cloud forests continue at current rates, but these effects could not be accurately quantified using available data. Therefore, based on expert opinion, it was conservatively assumed that under a BAU scenario, yields would be reduced by at least 25% relative to an intervention scenario. The value of this 25% increase in water supply compared to the BAU scenario which would be brought about by augmenting existing efforts to incentivize conservation action in the Mzima Springs recharge area was estimated to be at least US$3.26 million per year[45]. This assumes that the Chyulu Hills REDD+ project operational model is also strengthened.

[45] Using the unit cost of desalination (US$1/$m^3$) to value avoided reductions in water supply from Mzima Springs.

IMPACTS ON RAW WATER QUALITY

Nutrient-enriched runoff from agricultural and peri-urban land can have a negative impact on the water quality of downstream aquatic ecosystems. The excess nutrients introduced to these systems can change their trophic status in a process known as eutrophication. This is usually accompanied by increased abundance of algae and plant growth, which changes the nature and composition of these systems, affecting the benefits that can be derived from them. At extremes, it can lead to toxic algal blooms, loss of dissolved oxygen, and fish kills. Still water bodies, such as reservoirs, are particularly susceptible to this type of degradation. Where water is collected or extracted for drinking water supply, the elevated levels of algae, as well as nutrients and suspended sediments (TSS), increases the costs of water treatment. It is important to note that the sediment retention services of ecosystems are closely related to water quality amelioration services, in that suspended sediments are an element of water quality, and nutrients such as phosphorous which attach to sediments can be prevented from reaching downstream ecosystems as a result of sediment retention. Given that sedimentation is considered a major issue in the Mwache Dam catchment, the primary benefit to municipal water systems comes in the form of lowered sediment concentrations that reduce water treatment and maintenance costs.

Natural vegetation can help mitigate the effects of anthropogenic nutrient enrichment of aquatic ecosystems. Some of the nutrients in this enriched runoff can be removed when it passes through natural vegetation in the landscape, ameliorating the pollution problem before it reaches downstream ecosystems and locations where water is abstracted for use. Together, natural vegetation's active and passive services are valued as the costs avoided as a result of retaining the ecosystem in its natural condition.

In the absence of the service, increasing anthropogenic activity in water supply catchment areas leads to increasing water treatment costs in the following ways:

- Increases in pathogens, which usually come from wastewater treatment outputs and particularly from under-serviced human settlements, require the addition of chemicals such as chlorine.
- Increases in nutrients, which typically come from wastewater (as above) and fertilizers, result in increased phytoplankton growth, particularly in slower flowing rivers and in reservoirs.
- Increased phosphorus and suspended sediments are typically the problem in freshwater systems. Higher abundance of phytoplankton and fine sediments increases the requirement for chemical flocculants, dredging of settlement ponds and backwashing of filters with treated water, all of which also increase labour and energy requirements.
- Eutrophication also leads to toxic algal blooms that have to be treated with additional chemicals.

Impacts on raw water quality were estimated using the WEAP hydrological model. Phosphorous load balances and sediment concentrations were available at the reach scale at a daily and monthly time step. The model was set up to estimate changes in phosphorous loads and sediment concentrations at the proposed raw water treatment extraction point at Mwache Dam under the different scenarios. The value of the service was then estimated in terms of the avoided costs to the proposed water treatment works. This was calculated as the difference (cost saving) between the BAU and the MWF scenario for each year as a monthly $/ML cost saving. This was then multiplied by the proposed average monthly volume of water treated[46] to get an annual cost saving for the water treatment plant.

Under the BAU scenario the mean monthly P load is approximately 530 kg. The implementation of interventions throughout the catchment had a significant impact on reducing these loads, with phosphorous loadings being reduced to 149 kg. TSS concentrations in the Mwache River have been found to range from 912-1370 mg/l which is well above the 30 mg/l limit. Under the BAU scenario mean daily TSS concentrations were estimated to be 438 mg/l reaching 4500 mg/l on some days. The proposed interventions were assumed to reduce TSS concentrations by up to 40%.

Based on this, the water treatment cost saving is estimated to be approximately US$17/ML, which translates into an annual cost saving of some US$0.85 million[47], assuming a daily water treatment capacity of 140,000 m^3 for the proposed treatment plant.

ADDITIONAL BENEFITS OF RESTORATION AND CONSERVATION

OVERVIEW

There are a number of additional benefits that could arise from the MWF interventions, through changes in ecosystem condition and the supply of ecosystem services, other than those that are directly associated with formal water supply. These co-benefits include tangible livelihood benefits obtained by rural households from increased crop production, income and employment benefits from tourism and recreational activities, and avoided climate change costs to local and global society through retention of intact natural ecosystems.

CHANGE IN AGRICULTURAL PRODUCTIVITY

Rural populations in the study area rely primarily on agriculture for their livelihoods. Most rural households cultivate crops for subsistence, with fewer households cultivating cash crops grown for sale or bartering purposes. Maize is the dominant food crop, with smaller amounts of beans, cowpeas, and vegetables also cultivated (ESC, 2018a). Most of the Mwache Dam catchment is dry with low agricultural potential and the area is prone to periodic food shortages. Indeed, due to poor agricultural productivity, crop farming is in fact said to be declining in importance as a livelihood activity in the region. Less cultivation occurs in the sparsely populated western parts of the catchment, where livestock farming on group ranches is the dominant activity (Rural Focus Ltd, 2020).

Maize yields are significantly lower here than in other (wetter) parts of Kenya (MoALF, 2016). Total crop production from the catchment is estimated to be about 21 700 tonnes per year, with an estimated value of US$11.5 million per year[48]. If it is conservatively assumed that implementation of on-farm soil conservation interventions, which would reduce soil losses

[46] The reported capacity of the proposed water treatment works attached to Mwache Dam is 140,000 m^3 per day (https://www.afd.fr/en/carte-des-projets/mwache-water-treatment-plant-mombasa) which translates into a mean monthly treatment volume of 4256 ML.

[47] These are approximate estimates, since water quality is not closely monitored, their impact on raw water quality depends on dam conditions, and the dam and water treatment plants are yet to be built. Avoided costs were therefore estimated using a value transfer approach based on a model that was developed by Turpie et al., (2017), using monthly data.

[48] Maize yield of 0.561 tonnes/ha for Kwale County from (MoALF, 2016), mean price of maize KSh 49.20/kg from (KNBS, 2019b)

and improve water retention, would increase yields in the project sites by 25%[49], this would result in an increase in crop production value of US$1.1 million per year relative to a BAU scenario. In this study we allow for a delay of one year between implementation and the beginning of agricultural yield benefits.

NATURE-BASED TOURISM OPPORTUNITIES

Tourism is estimated to account for 8.2 percent of Kenya's total economy (WTTC 2020) and is a leading sector in terms of foreign exchange earnings and contributes significantly to total employment, especially in rural areas where economic opportunities are limited. Nature-based tourism, in particular wildlife viewing, is the backbone of the tourism industry in Kenya. Wildlife tourism is seen as key contributor to socio-economic development and a valuable source of income where tourism numbers and expenditure have been increasing steadily over the last 20 years (Valle & Yobesia, 2009; Okello, 2014; Price, 2017). A report by Sanghi *et al.* (2017) on the economic assessment of Kenya's tourism industry found that safari tourism generated greater economic growth than the other forms of tourism (business, beach, and other), addressed poverty problems, and created rural economic opportunities. When compared to the other forms of tourism, safari tourism was found to generate the highest GDP, as well as significantly greater household income. This is important, considering the limited economic opportunities in rural areas surrounding the protected areas in this region of Kenya.

Ecotourism is a key income-garnering activity in the Chyulu Hills PES Project Area (GNIplus, 2021a). Within the PES Project Area there is the Chyulu Hills National Park and the Tsavo West National Park which protects the Mzima Springs. Chyulu Hills, as per the Tsavo Conservation Area Management Plan, is designated as a low visitor use zone, whereas Tsavo West is a high visitor zone. The Mzima Springs are in fact a major tourist attraction in the region, supporting populations of hippos, crocodiles, fish, and birds, as well as acting as an important water source for migrating wildlife (GNIplus, 2021a). Within the PES Project Area there are two high-end lodges situated on Mbirkani and Kuku Group Ranches, as well as several smaller lodges and campsites. It is estimated that the total number of tourists to the PES Project Area is around 209 000 per year (GNIplus, 2021a).

Tourism in the Mwache Dam catchment is limited. Over the last few years there has been some development in ecotourism in the upper catchment areas where wildlife conservancies have been designated, creating corridors between Tsavo West and Tsavo East National Parks. Here, there has been a growth in the number of small tourist lodges and community tourism projects. The rest of the catchment, outside of these wildlife conservancies is less suited to ecotourism.

Tourism benefits to the study area (i.e., in-country tourism spend) were estimated in terms of direct value added to GDP, as a proxy for producers' surplus. This was estimated by disaggregating national-level tourism data to determine the contribution of Mwache Dam catchment and Chyulu Hills study areas. This was done using a combination of national and sub-national tourism data and the density of geotagged photographs uploaded to the internet[50] to map tourism value to ecosystems and other attractions (see Turpie *et al.*, 2017). Densities

49 This is a conservative estimate relative to Liniger *et al.*'s, (2011) higher estimate of 100-150%.

50 Tourism spend determined based on the density of geotagged photographs uploaded on the website flickr.com. These densities were obtained using the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) Recreation Model 3.5.0.

of geotagged photographs uploaded to platforms such as Flickr provide a means of mapping value to tourism attractions, rather than to the places where tourists spend their money (e.g., at their accommodations), so is more accurate in assigning the tourism spend to the actual attractions that caused the expenditure. The model calculates the average annual photo-user-days (PUDs) for each grid cell (5 km x 5 km) across the period 2005-2017. The model used the latitude/longitude data from photographs as well as the photographer's username and photo date to calculate PUDs. One PUD is one unique photographer who took at least one photo in a specific location on a single day.

Tourism's direct contribution to GDP was extracted for Kenya from the World Travel and Tourism Council – WTTC; WTTC 2020). The proportion of tourism expenditure attributed to visiting attractions, as opposed to activities such as visiting family and friends, attending conferences or religious events, or receiving medical treatment, was then estimated for each category of tourists (holiday, visiting friends and relatives, business, and other) based on information collated from Kenya tourism statistics reports and information related to tourist spending patterns (KNBS, 2020). Tourists whose main purpose is either visiting friends or family or business tend to spend much less of their money on visiting attractions than holiday/leisure tourists. These types of tourists do, however, make up a large proportion of the total tourism spending and so these contributions are not insignificant.

The total attraction-based tourism spend in 2019 for Kenya (prior to COVID-19) was estimated to be US$1.69 billion. This value was spatially allocated in proportion to photo density (from the InVEST Recreation Model) to generate an estimate of the value of the study area landscape, i.e., the proportion of the total attraction-based tourism spend associated with the natural areas within the Chyulu Hills PES Project Area and the Mwache Dam catchment. This represents the spend on nature-based tourism across the landscape. The total nature-based tourism spend in the study area was estimated to be US$20.4 million in 2019; US$8.8 million in Mwache Dam catchment and US$11.7 million in the PES Project Area (Table 8-2). This represents just 1.2% of the total attraction-based spend in the country.

Table 8-2. Nature-based tourism spend (US$ millions) in the Mwache Dam catchment and the Chyulu Hills PES Project Area and the change in this value under the BAU and MWF scenarios.

Study area	Baseline	BAU	MWF scenario
Mwache Dam catchment	8.8	7.8	8.9
Chyulu Hills PES Project Area	11.7	11.4	13.8

The per hectare values demonstrate the importance of the protected areas in attracting tourists and generating revenues. Within the Chyulu Hills PES Project Area, the mean tourism value was US$28/ha. However, the per hectare values were highest within the protected areas, with values as high as US$105/ha in Tsavo West and averaging US$17 in areas that were not protected. The mean per hectare value for the Mwache Dam catchment was US$24/ha.

The degradation and loss of natural habitat from these wildlife landscapes could have a significant negative impact on tourism spending. In order to estimate changes in tourism spend under the BAU and MWF scenario we assumed that degradation and loss would result in decreases in the mean per hectare values of these areas under a BAU scenario, or in the case of conservation interventions were restoration and improved protection results in gains in wildlife habitat, that the mean per hectare values in these areas could increase to be more in line with values currently seen in the protected areas. In the Mwache Dam catchment, tourism spending was expected to increase by about US$2.84 million annually by the end of the 30-yr analysis period compared to the BAU. The gains were estimated to be slightly higher in the Mzima Springs recharge area, at US$3.07 million per year by 2050 when compared to the BAU. This is based on the assumption that the PES scheme will provide better management and protection of wildlife habitats and will provide further opportunity for community tourism projects in the areas adjacent to the protected areas. These gains are also unlikely to be immediate, taking some time to materialize.

CARBON STORAGE AND SEQUESTRATION

Natural systems are known to make a significant contribution to global climate regulation through the sequestration and storage of carbon. About half of the biomass of vegetation, both above and below ground, comprises carbon. Furthermore, carbon accumulates in the soils and peat as a result of the accumulation of leaf litter and partially decayed biomass. The capacity for carbon sequestration and storage therefore varies between different types of ecosystems and in different locations. When natural systems are degraded or cleared, much of this carbon is released into the atmosphere. These emissions contribute to global climate change, which is contributes to changes in biodiversity and ecosystem functioning, changes in water availability, more frequent and severe droughts and floods, increases in heat-related illness, and impacts on agriculture and energy production (IPCC, 2007). These impacts will affect economies and human well-being on a global scale, but more so in developing countries that are more reliant on land and natural resources (Tol, 2011). Adaptation to these changes could come at a high cost. The protection and restoration of natural systems thus helps to reduce the rate at which greenhouse gases accumulate in the atmosphere and the consequent impacts of climate change. This benefits Kenya as well as the rest of the world. The benefits to the rest of the world can also produce local revenues through mechanisms such as the UN's Reduced Emissions from Deforestation and Degradation (REDD+) program. This is the case in Mzima Springs recharge area where the Chyulu Hills REDD+ Project has been in operation since 2013.

This assessment includes estimates of carbon storage for the Mwache Dam catchment and for the Mzima Springs recharge area (i.e., Chyulu Hills). For the Mzima Springs area we have relied on estimates of carbon stocks and changes in these stocks under future scenarios from the AECOM (2021) Chyulu Hills PES Project Report.

Mwache Dam catchment

Based on global datasets derived from satellite data (see FAO & ITPS, 2018; Spawn & Gibbs, 2020), it was estimated that approximately 17.1 million tons of carbon are stored within the vegetation and soils of the Mwache Dam catchment (Table 8-3). The amount of carbon stored ranged from as low as 24.2 t/ha in the degraded grassland areas of the upper catchment to as much as 140.9 t/ha in the forested areas of the catchment, with a mean value of 47.4 t/ha. This translates into 63.1 million tCO_2e.

Table 8-3. The total amount of carbon stored within the Mwache Dam catchment and summary statistics (tC/ha), in metric tons.

	Total stock of carbon (tons)	Mean (tC/ha)	tCO_2e
Mwache Dam catchment	17 187 278	47.4	63 077 311

The carbon retention value of these stocks was valued in terms of the avoided losses of economic output by Kenya as well as the rest of the world, using recently published estimates of the global and disaggregated country-specific damage effects of climate change (see Ricke *et al.*, 2018b). These damage estimates are called the "social cost of carbon" (SCC) and are expressed as US dollars per ton of CO_2 emissions. Thus, carbon stocks were first converted to the equivalent quantity of CO_2[51]. The stocks were also valued using the average sales price of carbon credits sold through the REDD+ Project (US$6.38, i.e., representing a market value)[52].

Estimates of the global social cost of carbon (GSCC) vary greatly, depending on the climate change scenario, the design of the integrated assessment model (IAM) and the choice of discount rate. By 2008, there were at least 232 published estimates of SCC, the average of which was about US$33/t$CO_2$ (Tol, 2008). In an effort to refine these estimates, the more recent literature has also tended to broaden the types of damage costs considered, increasing the estimates of SCC. Thus, estimates now range from US$10 to US$1000/tCO_2 (Ricke *et al.*, 2018). In their critical review of the literature, Van Den Bergh & Botzen (2014) suggested a lower bound value of US$125/t$CO_2$. A recent expert meeting of scientists and economists found a mean SCC of US$150-200/t$CO_2$.

More recent studies have also attempted to disaggregate these global SCC estimates to regional or country level. For example, Nordhaus (2017) provided an updated median estimate of global SCC as US$31/t$CO_2$ (in 2010 US$) and estimated that 3% of this would be borne in Africa. Ricke *et al.* (2018b) produced a far higher median estimate of global SCC (US$417/t$CO_2$ in 2018 US$; US$177-US$805) and disaggregated this to country-level, with the estimated cost to Kenya being US$0.61, which is 0.15% of the global SCC estimate.

In this study, we applied both the SCC values of Ricke *et al.* (2018b) and Nordhaus (2017) as the higher and lower bound estimates to form part of a sensitivity analysis and used the average of these two estimates (US$249/t$CO_2$ in 2021 US$; Table 8-4) to estimate the total value of carbon storage in the study area from both a global perspective and a Kenyan perspective (using 0.15% as estimated by Ricke *et al.*, 2018b).

Table 8-4. The estimates of the Global and Kenyan SCC values per tCO_2 used in this study based on values from Nordhaus (2017) and Ricke et al. (2018), all in 2021 US$.

	Nordhaus (2017)	**Ricke *et al.* (2018)**	**Mean estimate**
Global SCC per tCO_2 2021	47	451	249
Kenya SCC per tCO_2 2021	0.07	0.66	0.36

The SCC is a net present value of avoided costs, typically over 100 years. However, values must be determined for each year because of the staggered implementation of MWF interventions over the 30-year time period. Thus, the annualised social cost of carbon (ASCC) was estimated based on Turpie *et al.*, (2020). For this study, we assumed t = 100 years, and we used a social rate of discount of 6.52% (from Addicott, Fenichel & Kotchen, 2020). Based on this, an annualised GSCC of US$13.10 was used. It is important to note that these estimates are likely conservative as the value of SCC is not static and is expected to increase over time as populations and per capita incomes grow.

51 The ratio of CO_2 to C is 44/12 = 3.67.

52 AECOM (2021), based on sales of carbon credits made through the REDD+ scheme to date.

The total global damage costs avoided by retaining the total stock of biomass carbon is significant at almost US$826 million/y (Table 8-5). The avoided damage cost to Kenya is estimated to be US$1.2 million/y. The market value of this stock of carbon, if sold through a carbon credits scheme, would have an estimated value of US$13.4 million/y.

Table 8-5. Stock of carbon in the Mwache Dam catchment under the BAU and the MWF scenario, and the global and national carbon storage values per year (US$ 2021).

	Baseline	BAU	MWF Scenario
Stock of carbon (million tC)	17.2	16.8	17.3
Carbon storage global (US$ m/y)	826.4	807.9	830.5
Carbon storage national (US$ m/y)	1.20	1.17	1.21

Under the current trajectory, a total of approximately 382 600 tC could be lost over the 30-yr analysis period (Table 8-5). The analysed nature-based solutions not only would avoid this BAU degradation of carbon stocks but would increase current carbon sequestration and storage through agroforestry, farmer managed natural regeneration and active restoration, resulting in net gains of 467 000 tC compared to the BAU scenario. This would result in avoided climate-related damage costs of about US$22 million at a global scale, and some US$0.03 million to Kenya. Furthermore, the establishment of a community wildlife conservation area in the central northern part of the catchment would link the adjacent Tsavo East National Park and the existing Shirango Conservancy to other Tsavo Region conservancies and the Wildlife Works Kasigau Corridor REDD+ Project ranches in the west[53]. This conservation area spans approximately 20 000 ha and could potentially, through the Kasigau Corridor REDD+ Project, generate earnings of US$0.2 million per year through the sale of carbon credits[54].

Mzima Springs recharge area (Chyulu Hills)

Based on information extracted from the Chyulu Hills PES Project Report (GNIplus, 2021a), it was estimated that approximately 5.3 million tons of carbon are stored within the forest and grassland areas of the Chyulu Hills, equating to 19.5 million tCO_2e. The same approach as used for the Mwache Dam catchment was used here to estimate the carbon retention value of these stocks. The total global damage costs avoided by retaining the total stock of biomass carbon is estimated to be US$255 million/y. The avoided damage cost to Kenya is estimated to be US$373 000/y. The market value of this stock of carbon, if sold through a carbon credits scheme, would have an estimated value of US$4.1 million/y (Table 8-6).

Estimates of carbon losses and gains under future scenarios were based on the scenario analysis undertaken by AECOM as part of the Chyulu Hill PES study (Figure 8-1; see AECOM, 2021). The BAU was considered to be the REDD+ continuation scenario under which deforestation would increase from 36% to 45% over the 30-year period as a result of funding shortfalls. The future PES scenario with afforestation was considered as the future scenario

[53] In 2011, the Wildlife Works Kasigau Corridor REDD+ Project was successfully validated and verified under the Verified Carbon Standard (VCS) and the Climate, Community and Biodiversity Standard (CCB). Today, there are 16 conservancies participating in the Project with more than 200 000 ha of forest and bushland protected, securing the wildlife migration corridor between Tsavo East and Tsavo West National Parks.

[54] Based on 1.6 million tonnes of mitigated carbon annually with gross earnings from carbon credit sales of KSh360 million (~US$3.2 million) in 2018 and 2019; TTWCA (2020).

with the implementation of the Chyulu Hills water PES under the MWF. Under this scenario, the forests are protected and additional ANR and tree planting activities are undertaken through the PES program. This could result in an estimated gain of 58 000 ha of forest over the 30-year time period (GNIplus, 2021a).

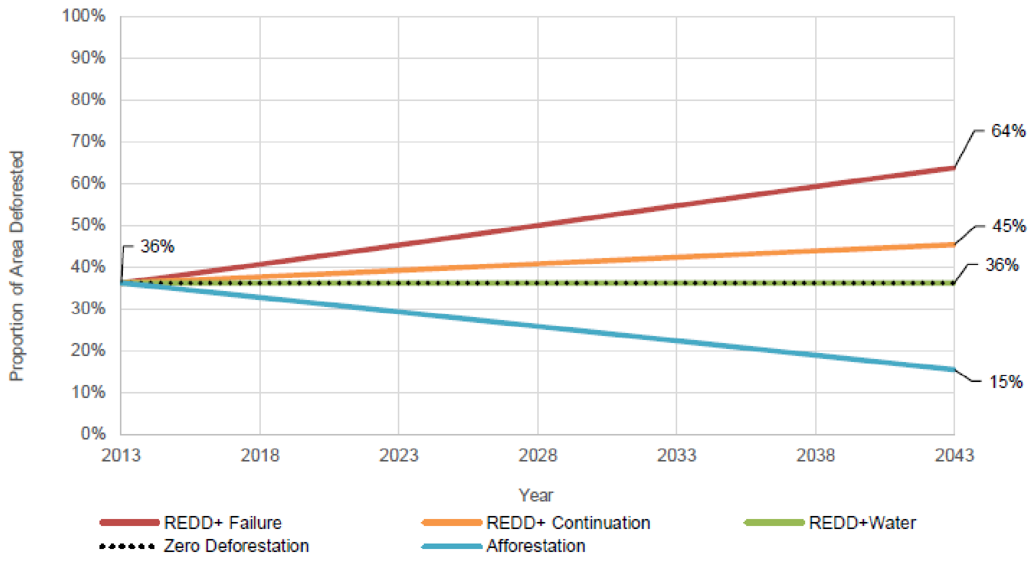


Figure 8-1. The four scenarios analysed as part of the Chyulu Hills PES study. Source: AECOM 2021.

Following a 'do nothing' approach under the BAU, it is estimated that a total of 478 200 tC could be lost through encroachment and deforestation, resulting in annual global losses of some US$23 million (Table 8-6). A total of 8.1 million tC could be gained under the Afforestation PES intervention as a result of the PES community forest conservation and restoration activities implemented across the Chyulu Hills. In addition to the avoided climate related damage costs, the residual gains in carbon relative to the BAU scenario, as a result of halting deforestation and ensuring afforestation of some 58 000 ha through the PES scheme, could be worth about US$2.3 million per year at current market prices for carbon[55].

Table 8-6. Stock of carbon in the Chyulu Hills under the BAU and the MWF PES scenario and the global and national carbon storage values per year (US$ 2021).

	Baseline	BAU	PES
Stock of carbon (million tC)	5.3	4.8	13.4
Carbon storage global (US$ m/y)	255.4	232.5	648.4
Carbon storage national (US$ m/y)	0.37	0.34	0.95

55 Based on sales of carbon credits made through the Chyulu Hills REDD+ Project to date; GNIplus (2021).

THE VIABILITY OF THE MWF

COST-BENEFIT ANALYSIS

The costs and benefits of the proposed MWF restoration and conservation interventions described above were analyzed using a cost-benefit analysis (CBA) to quantify the net present value and overall return on investment (ROI, net welfare gains per US$ invested). Cost-benefit analysis is used to evaluate the viability and desirability of projects based on their costs and benefits over time. It involves the adjustment of future values to their present value equivalent by discounting at a rate which reflects the potential rate of return on alternative investments or the rate of time preference. For a project to be considered viable, the net present value (NPV) must be positive.

Discounting places greater weight on values occurring closer to the present, which means that the future benefits of restoration projects will be down-weighted compared with the upfront investment costs, and have to be substantial in order for a project to be viewed positively. In this analysis the upfront capital costs associated with the proposed interventions are in most instances considerable, in addition to the annual ongoing monitoring and/or maintenance costs. Furthermore, many of the benefits are not realised immediately with the time taken for the proposed interventions to generate meaningful impacts only occurring in the future (e.g., two to five years down the line). For example, the benefits of active restoration were assumed to only be realized in year five. The quantitative nature of cost-benefit analysis does not necessarily indicate certainty. Accurately estimating and forecasting all of the associated costs and benefits can be challenging. Studies are usually limited by availability of data and resources, as well as uncertainty in the consideration of changes in factors such as land use, climate, household incomes and rates of urbanisation, for example.

For this analysis the social rate of discount that takes future generations into account was used (for Kenya this is 6.52%, taken from Addicott et al., 2020) over a time period of 30 years. This was further tested under varying assumptions of costs, benefits and discount rate. The costs and benefits of certain interventions were varied under a range of assumptions to get a better understanding of the viability of the two MWF scenarios. This included an exploratory analysis of the impact of changing assumptions about new conservation areas in the catchment and production gains associated with the agricultural interventions, as well as varying the timing of restoration benefits. Furthermore, a NPV sensitivity analysis was undertaken using discount rates of 3% and 9%. In this study we compare the MWF scenario to the 'do nothing' BAU scenario. This is achieved by dividing the difference in benefits of the MWF scenario versus the BAU scenario by the costs of restoration interventions in achieving the conservation and social outcomes. This produces a benefit-cost ratio (BCR) or return on investment (ROI), which suggests how many units of benefit each unit of cost brings.

Contributions to the Chyulu Hills PES Scheme through the MWF to ensure protection of the cloud forests could generate benefits in the order of US$92 million over the 30-year time frame (Table 8-7.). This represents a return of some US$1.30 in benefits for every dollar spent. However, the benefits could be far greater than this, as the Chyulu Hills also support significant biodiversity and wilderness areas, which are valued both by Kenyan citizens and by global society, and which contribute to Kenya's biodiversity conservation commitments. There are a great number of people, including many who may never visit the area, who would have a positive willingness to pay for conservation of this landscape. These non-use values could greatly exceed the tourism value of this area.

Table 8-7. Present value of the costs of interventions and value of ecosystem service benefits for Mwache Dam catchment and Mzima Springs recharge area (2021 US$ millions, 6.52% discount rate, 30 years).

	Present value (US$ millions)		
	Mwache Dam catchment	**Mzima Springs recharge area**	**Combined**
Costs			
Restoration of riparian and other forest cover	1.3		1.3
Soil conservation measures on cultivated land	11.2		11.2
Sustainable natural resource management and conservation	18.8		18.8
Community forest management: Chyulu Hills Water PES	-	72.5	72.5
Total present value of costs	**31.3**	**72.5**	**103.8**
Benefits: Mwache Dam catchment			
Impacts on water yield	6.9	-	6.9
Savings on check dam dredging	11.9	-	11.9
Avoided water treatment costs	8.2	-	8.2
Production gains from agriculture interventions	12.9	-	12.9
Carbon gains*	2.3	-	2.3
Increase in tourism and recreation opportunities	23.3	-	23.3
Benefits: Mzima Springs recharge area			
Impacts on water yield	-	31.3	31.3
Carbon gains*	-	32.5	32.5
Increase in tourism and recreation opportunities	-	27.8	27.8
Total present value of benefits	**65.4**	**91.6**	**157.0**
Net Present Value	**34.1**	**19.1**	**53.2**
ROI	**2.1**	**1.3**	**1.5**

* These results include the market value of carbon (if sold through the Chyulu Hills REDD+ Project or the Wildlife Works Kasigau Corridor REDD+ Project) as well as the avoided climate-related damage costs to Kenya.

Investments in the Mwache Dam catchment are expected to have even better returns. Here, a US$31 million investment in restoration interventions is expected to return at least US$65 million in economic benefits over the 30-year timeframe (Table 8-7.). In other words, every US$1 invested by the Water Fund is expected to generate at least US$2.10 of included benefits to stakeholders. Again, in addition to the water security and tangible co-benefits included in the calculations, this would also come with some biodiversity benefits, in that improved conservation in the upper part of the catchment would increase wildlife habitat and the connectivity of conservation areas in the region. Taken together, the overall investment costs would amount to US$104 million, with returns of US$157 million, resulting in a net present value of US$53 million and an ROI of 1.5. Figure 8-2 shows how the benefits, costs and net annual benefits are anticipated to be realized over time for the Mwache Dam catchment and Mzima Springs recharge area.

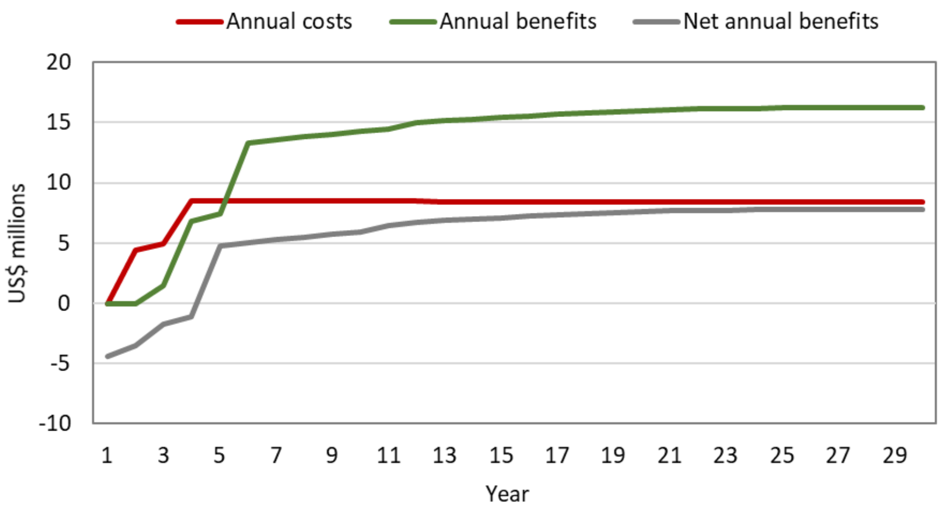


Figure 8-2. Total annual benefits and costs over time for the extended analysis of the Mwache Dam catchment and Mzima Springs recharge area (2021 US$ millions, 30 years).

SENSITIVITY ANALYSIS

Under varying assumptions of costs and benefits and timing and discount rates, the results of the analysis remain favorable, but only just in some cases. Changing the assumption around agricultural yields to be more conservative reduced the ROI to 1.4 and removing community conservation areas increased the ROI slightly to 1.5. The ROI for the Mwache Dam catchment remains positive at 1.3 even when tourism benefits are excluded from the analysis. However, while the net benefits remain positive under varying assumptions, the overall viability of the MWF is sensitive to changes in the timing of benefits as well as in terms of the costs of interventions. Increasing costs and decreasing the benefits by 15% dropped the ROI to 1.1 and delaying restoration benefits by a further three years dropped it to 1.2, with a net present value of US$9.6 million and US$19.1 million, respectively.

Table 8-8. Sensitivity analysis under varying assumptions of intervention, timing of benefits, and discount rate (2021 US$ millions, 6.52% discount rate, 30 years).

	Present value & ROI after change (US$ millions)
Without community conservation areas in place	
Total present value of costs	90.0
Total present value of benefits	131.0
Net Present Value	**41.0**
ROI	**1.5**
Gain in agricultural yield reduced to 10%	
Total present value of costs	103.8
Total present value of benefits	144
Net Present Value	**40.2**
ROI	**1.4**
Varying the timing of restoration benefits to be 3 years later	
Total present value of costs	103.8
Total present value of benefits	122.9

Net Present Value	**19.1**
ROI	**1.2**
15% increase in costs & 15% decrease in benefits	
Total present value of costs	119.4
Total present value of benefits	129.0
Net Present Value	**9.6**
ROI	**1.1**
Increasing the discount rate to 9%	
Total present value of costs	80.6
Total present value of benefits	112.5
Net Present Value	**31.8**
ROI	**1.4**

CONCLUSIONS

In addition to security in water supply and water quality, expanded forest protection, active restoration of degraded forest areas and rangelands, and community support for sustainable agriculture in the eastern community areas and improved grazing and rangeland management in the pastoralist areas in the Chyulu Hills could bring wider benefits. These include nature-based tourism, climate change resilience, job creation, opportunities for women and most importantly, avoiding the irreversible loss of the unique and valuable biodiversity of this area. While the overall viability of the MWF could be sensitive to changes in the timing of benefits as well as in terms of the costs of interventions, the sensitivity analysis shows that even under these conditions, economic viability can still be maintained.

The following key results demonstrate the importance of catchment restoration and conservation and the feasibility of establishing the MWF. Compared to a business-as-usual scenario, investing in catchment ecological infrastructure would yield the following returns:

- The amount of sediments entering the rivers of the Mwache Dam catchment would be reduced by approximately 16% (109 000 tonnes), with an annual cost saving in terms of dredging sediment check dams of US$1.23 million per year;
- A 1% loss in average annual water yield from the Mwache Dam catchment could be prevented, which translates into avoided costs of US$0.38 million per year for the first five years, US$0.42 million per year for the next five years, and US$0.75 million per year after that;
- Losses of at least 25% in water yield from the Mzima Springs could be prevented, translating into avoided costs of at least US$3.26 million per year;
- The amount of phosphorous and TSS entering the rivers of the Mwache Dam catchment could be reduced by 70% and 50%, respectively, with annual avoided water treatment costs of around US$0.86 million per year;
- Agricultural interventions implemented on cultivated land could increase agricultural productivity through improved crop yields, generating increases in annual returns of US$1.07 million per year to farming households;
- Carbon stored in the study area would be 9.1 million tonnes higher over the 30-yr study horizon, avoiding estimated annual climate change damages of US$640 000 to

Kenya and US$438 million at a global level, with a current carbon market value of US$2.50 million per year;

- Increased tourism related spending across the study area could amount to US$5.90 million annually by 2050; and
- Nature-based solutions will have a positive impact on the pollination of crops in nearby fields by insect pollinators that are supported by natural habitats, cultural values derived from improved community forest management in Kwale county, nutritious (and income earning) fruits from fruit trees planted in agroforestry systems, human and livestock health benefits associated with the cooling services provided by agroforestry systems, and the potential health benefits as a result of reduced coliform loadings into waterways through rehabilitation of riparian buffers.

PART IV. POLICY, LEGAL AND INSTITUTIONAL CONTEXT AND STAKEHOLDERS

9 POLICY, LEGAL AND INSTITUTIONAL LANDSCAPE

OVERVIEW

This section appraises the existing policies, laws and institutions involved in catchment protection and conservation and water resources management and development in Kenya. The analysis was undertaken to help understand how policy, legal and institutional frameworks enable or restrict the establishment of the proposed Mombasa Water Fund (MWF). In Kenya, water resources management has embraced a catchment area approach. This approach is operationalized through the Water Act (2016), and aligned with the devolved framework of the Constitution of Kenya (2010), where county governments have responsibility for water service provision and implementation of specific national government policies on natural resources and environmental conservation, including soil and water conservation and forestry. However, catchment protection and conservation, water storage and flood control are shared functions with the national governments. The Policy, legal and institutional frameworks relevant to catchment protection and sustainable water resources management and development are discussed below.

POLICY FRAMEWORKS

THE CONSTITUTION OF KENYA

The Constitution of Kenya (2010) provides the basis for catchment protection and water resources management and development. Its preamble gives prominence to the environment, which is described as a national heritage to be sustained for the benefit of future generations.[56] Water catchment areas serve critical functions in maintaining the country's water supply.

Article 10 of the Constitution recognizes sustainable development as one of the national values and principles of governance that is binding in all aspects of public policy.[57] The national government is required to ensure sustainable exploitation, utilization, management and conservation of the environment and natural resources, and ensure the equitable sharing of the accruing benefits.[58] Under the Constitution of Kenya (2010), the national government is functionally responsible for the ownership, use and regulation of water resources. However, planning, catchment protection and conservation, water storage and flood control are shared functions with county governments, which are also mandated to provide water and sanitation services, and implement specific national government policies on natural resources and environmental conservation, including soil and water conservation and forestry.[59] While the Constitution places a mandate on counties to implement specific national government policies

[56] The preamble of the Constitution of Kenya (2010).
[57] Article 10 (1) of the Constitution of Kenya (2010).
[58] Article 69 (1) (a) of the Constitution of Kenya (2010).
[59] Fourth Schedule Part 1(22) and Part 2 (10 & 11) of the Constitution of Kenya (2010).

on natural resources and environmental conservation, there is a lack of legal clarity on the institutional mechanisms through which counties can perform these functions.

The Constitution of Kenya (2010) reinforces sustainability with its provisions on the right to a clean and healthy environment,[60] and the social and economic right to clean and safe water of adequate quantities.[61] Article 42 of the Constitution guarantees the right to a clean and healthy environment, through the management and sustainable development of natural resources. The Constitution further imposes an obligation on the State and citizens to protect the environment. These constitutional provisions provide a strong overarching foundation upon which payment for environmental services schemes, such as water funds, can be developed and implemented for the protection and conservation of water catchment areas.

The conservation of water catchment areas focuses not only on water resources but on related ecosystems such as land and forests. Chapter Five of the Constitution addresses these issues particularly through the provisions of Articles 60 on principles of land policy; 66 on regulation of land use; and 69 on enforcement provisions with respect to the environment, in which the State is mandated to ensure sustainable exploitation, utilization, management and conservation of the environment and natural resources. These provisions present a good basis for integrated management of water resources.

The Constitution puts a duty on every person to cooperate with State organs and other persons to protect and conserve the environment and ensure ecologically sustainable development and use of natural resources.[62] This provision implies that citizens are under a duty to cooperate with the State in the carrying out of any lawful measures as may be necessary for environmental protection and conservation of natural resources, including measures for watershed management.

Socio-economic rights guarantee basic standards of subsistence that are essential to human dignity. These rights, which include the human right to water, food, health and social security cannot be fully provided for unless specific measures are taken to protect and conserve water catchment areas. In recognizing the human right to safe water and sanitation, the Constitution compels the state to put in place measures to improve access to water in adequate quantities. The right to water in adequate quantity is interpreted broadly to include social and economic values of water. To secure the fundamental human right to water, the role of government is to act reasonably in the pursuit of policy and legislation that ensure the right is fulfilled, supported by appropriate funding, governance structures, watershed protection and other measures.

KENYA VISION 2030

Kenya's long-term planning instrument, *the Vision 2030*, prepared in 2008, strives to create a globally competitive, middle income and prosperous country, providing high quality of life for her citizens by 2030.[63] The Vision is inspired by the principle of sustainable development, but is anchored on three pillars that do not include the environment: economic, social, and political. The economic pillar aims to achieve and sustain a 10 percent annual economic growth

[60] Article 42 of the Constitution of Kenya (2010)
[61] Article 43 of the Constitution of Kenya (2010)
[62] Constitution of Kenya (2010). Art. 10 (2)(d).
[63] Kenya Vision 2030

rate through 2030, which is also an unsustainable goal.[64] Environment is relegated to the social pillar, which strives to create a just, cohesive and equitable society in a clean and secure environment.[65] The political pillar seeks to realize an issue-based, people-centred, result-oriented and accountable democratic system.[66] The achievement of these targets is premised on sustainable management of natural resources including watershed protection and conservation, and strengthening of institutional capacities for environmental governance.

Water management is critical in realizing the strategic targets under the three pillars of Kenya Vision 2030. Such targets include ensuring improved water supply and sanitation services; increasing the acreage under irrigation to 1.2 million ha by 2030; ensuring a clean, secure and healthy environment; and generating more hydro-electricity to drive economic growth. Similarly, a number of flagship water development projects have been prioritized under the Vision 2030. These include the rehabilitation and protection of Kenya's five major water towers (i.e. the Aberdares, Cherangani, Mau, Mt. Kenya and Mt. Elgon) to guarantee improved water supply for social and economic needs, and the integrity of ecosystems.

NATIONAL WATER POLICY (1999)

Following the development of the National Policy on Water Resources Management and Development (Sessional Paper No. 1 of 1999), the reforms in the water sector transitioned from centralized decision-making towards decentralization and integration. Throughout the 20th century, water policy was characterized by a hierarchical top-down command-and-control approach. This mode of governance was associated with water governance challenges, such as weak coordination among actors, weak inter-linkages with water-related sectors, institutional fragmentation and conflicts, and insufficient financial resources for water resources management and development.[67] However, at the turn of the 21st century, there was a shift towards separation of functions, including water resource management, water service delivery and policy; decentralization of decision making; commercialisation of water; and stakeholder participation through communities and private sector. The reforms underscored the dominance of markets as mode of governance, over central regulation. This was based on the realization that deliberative governance would promote accountability and efficiency in water management.

The National Policy on Water Resources Management and Development provides specific policy objectives on water resources management, water supply and sewerage development, institutional arrangements and financing of the water sector. In particular, it seeks to (i) preserve, conserve and protect water resources, and allocate it in a sustainable, rational and economical way; (ii) supply water of good quality and in sufficient quantities to meet the various needs; (iii) establish an efficient and effective institutional framework to achieve systematic development and management of the water sector; and (iv) develop a sound and sustainable financing system for effective water resources management, water supply and sanitation development. Of particular importance, the policy redefines the role of the government in water management with emphasis on regulatory and enabling functions. The enabling provisions provide for efficient and effective management of water resources,

64 Ibid,
65 Ibid
66 Ibid
67 Republic of Kenya (1999). The National Policy on Water Resources Management and Development, Sessional Paper No. 1 of 1999. Nairobi

mechanisms for incentives and achieving financial sustainability and harmonization of sectoral policies.

The National Water Policy recognized the importance of environmental flows. Based on the findings of the nation-wide water resources assessment carried out under the National Water Master Plan Study between 1990 and 1992, it was evident that the surface and groundwater resources were unevenly distributed both in space and time. This was attributed to the variability in rainfall and the diverse climatic and geological conditions. As a result, the surface and groundwater flow, vary considerably. Land use land cover change, particularly in the water catchment areas, constitutes a major threat to the country's water resources, not only in respect of siltation, but also as regards the run-off, water balance and groundwater recharge characteristics. The effect has been the diminishing of the available water resources. The Policy noted that basic solution to these problems lay in the preservation, conservation and development of national water resources in the most feasible manner. Further, the Policy emphasized the role of public-private partnerships (PPP) in water resource governance and development, and delegated water resource management and service provision to the private sector, local authorities and communities. Whereas the development of sustainable financial systems for effective water resources management and water supply are emphasized in water policy, little attempt was made to provide an innovative funding mechanism for watershed protection and conservation. The policy did not advocate for incentive mechanisms to facilitate the implementation of nature-based source water protection measures.

The aspirations of the 1999 national water policy found legislative expression in the Water Act (2002), which separated water resources management from water services provision; defined institutional roles of policy making, regulation, management and service provision; devolved functions to regional and local units; allowed participation in water resources management; and commercialized service provision. The Act created Water Resources Management Authority (WRMA) and Water Services Regulatory Board (WASREB) as regulators, devolved functions to Catchment Area Advisory Committees (CAACs) and Water Services Boards (WSBs), made provision for establishment Water Resource Users Associations (WRUAs), and required local authorities to establish Water Service Providers (WSPs). Despite growing appreciation of the separation of water resources management from service provision, the arrangement weakened the existing customary water governance arrangement in many rural communities which uphold the integration of water resources management and service provision.[68]

Despite the gains made in the management of water resources under the 2002 water reforms, many challenges still confound the water sector. Such challenges include weak coordinating capacities between national government, its agencies and county governments; weak participatory decision-making processes; increased conflicts and disputes over water access rights; degradation of water catchment areas and encroachment on wetlands and riparian reserves; and lack of a clear and coherent policy on rainwater harvesting and storage. Subsequently, a new National Water Policy is currently being developed to replace the 1999 Water Policy, and align water sector reforms with the devolved framework of the Constitution (2010) and other emerging realities relevant to the water sector, such as, the Kenya Vision 2030. The review is expected to pay particular attention to coordinating capacity

[68] Gachenga, E. (2015). Customary law system for water governance in Kenya. In P. Martin et al., the search for environmental justice. The IUCN Academy of Environmental Law Series, Edward Elgar Publishing, UK

challenges that are most evident between the national government, its agencies and county governments.

ENVIRONMENTAL SANITATION AND HYGIENE POLICY 2016-2030

The Constitution of Kenya (2010) provides the overarching framework for all policies. Article 19 (1) (2) in particular sets the Bill of Rights, which applies to all laws and binds all state organs and all persons, as the framework for social, economic and cultural policies in Kenya. The purpose is to preserve the dignity of individuals and communities and to promote social justice.[69] It is against this background that a sanitation and hygiene policy was formulated. For purposes of this study, the following salient features are discussed below. These include:

a. Household Water Treatment and Safety.

This policy recognizes that unsafe drinking water, along with inadequate hygiene and sanitation contributes much of the disease burden in Kenya. Studies have also found that the benefits of a water quality intervention depend on sanitation and hygiene conditions.

b. Wastewater Management

Wastewater or liquid waste is any spent or used water from homes, communities, farms and commercial and industrial entities that contains enough harmful material to damage the water's quality. Wastewater includes sludge from on-site sanitation systems such as pit latrines, Urine Diverting Dry Toilets (UDDT) and septic tanks, domestic sewage and industrial waste from manufacturing sources. To effectively manage the increasing volumes of wastewater from various sources as the economy grows, county governments in collaboration with the National Environmental Sanitation Coordinating and Regulatory Authority (NESCRA), Water Services Regulatory Board (WASREB) and other relevant regulatory agencies shall have authority to regulate, control, and coordinate the activities of all agencies involved in liquid waste management services.

c. The Role of Development Partners

Development partners, including multilateral and bilateral agencies, international NGOs and private foundations have a role to complement national and county government efforts in the environmental sanitation sector. The assistance may include intermittent budget support, technical assistance, capacity building, institutional development and reforms, capital development financing, development and implementation of sector policies, research and development, monitoring and evaluation.

NATIONAL LAND POLICY (2009)

The National Land Policy (NLP) sets a framework to address questions around land in Kenya, particularly those related to land tenure, restitution for historical and contemporary claims of land injustices and sustainability of land resources.[70] Past land policies recognized the superiority of private land tenure over customary arrangements.[71] As a result, customary land

---

[69] https://www.wsp.org/sites/wsp/files/publications/Kenya%20Environmental%20Sanitation%20and%20Hygiene%20Policy.pdf (accessed 11 March 2021)

[70] Republic of Kenya (2009). *Sessional Paper No.3 of 2009 on National Land Policy* (Nairobi: Ministry of Lands, August 2009)

[71] Okoth-Ogendo, H. W.O. (1995). Terminology and land tenure in Customary law: An exercise in linguistic theory. In Woodman, G. & Obilade, A. O. (Eds.), African law and legal theory. New York University Press, New York.

rights were extinguished and replaced with private tenure which prioritized economic productivity over equity and sustainability in the use of land. Subsequently, the NLP (2009) brought about a momentous turnaround in land policy reforms, adopting a plural approach where different forms of tenure, such as public, private and communal land ownership arrangements co-exist and benefit from equal guarantee of tenure security.[72] The plural approach is premised on the philosophy that equal recognition and protection of all forms of tenure will enable the realization of economic productivity, equity, environmental sustainability and cultural preservation in the use of land.[73]

The NLP outlines several principles for sustainable management of land. These include equitable access to land, secure lands rights, intra- and inter-generational equity, effective regulation of land development, sustainable land use and productive land management.[74] Security of land rights refers to whether an individual's right to land is recognized and protected by the law. Sustainable and productive use of land incorporates an understanding that social and economic benefits flowing from use of the land must be obtained in a manner that does not harm environmental sustainability. In the absence of adequate environmental sustainability, the state reserves the right to apply the principle of effective regulation of land.

Land tenure denotes the terms and conditions under which rights to land and land-based resources are acquired, retained, used and disposed of or transmitted.[75] The NLP recognizes three land tenure categories, namely: public land, community land and private land.[76] Public land refers to land that is neither privately nor communally owned, or any other land declared to be public by an Act of Parliament.[77] Community land, on the other hand is land that is lawfully held, managed and used by a given community.[78] Private land is land lawfully held, managed and used by an individual or other entity under statutory tenure.[79]

The NLP takes note of the relevance of land tenure to sustainable and productive land use. Land tenure confers user rights and obligations to landowners to make decisions over productive and sustainable use of land. The private entitlements and obligations that exist in relation to land ownership and use can create incentives for sustainable use of land and related resources.[80] However, in the course of using the land and related resources for socio-economic benefit, many landowners fail to incorporate environmental considerations into land use management. The absence of environmental obligations in tenure rights justifies the application of state authority to regulate private interest in land or even abrogate property rights over land, in the interest of sustainable development.

The NLP retains the principles of eminent domain (compulsory acquisition) and police power (development control) in sustainable management of land and related resources. Eminent domain denotes the power of the state to compulsorily acquire private property for public

---

72 Republic of Kenya (2009), Op.cit, P.9
73 Ibid, P.9
74 Ibid, p.2
75 Ibid, p.13
76 Ibid, p.13
77 Ibid, p.14
78 Ibid, p.14
79 Ibid, P.16
80 Kameri-Mbote, P. (2006). Land Tenure, Land Use, and Sustainability in Kenya: Toward Innovative Use of Property Rights in Wildlife Management. In N. Chalifour, P. Kameri-Mbote, L. Lye, & J. Nolon (Eds.), Land Use Law for Sustainable Development (IUCN Academy of Environmental Law Research Studies, pp. 132-160). Cambridge: Cambridge University Press

purposes, subject to prompt and just compensation. Police power, on the other hand, connotes the command of the state to regulate land use in the public interest.[81] The acquisition of private property through eminent domain is rarely done to pursue environmental agendas, but rather to advance the state's socio-economic interests. The police power principle has been used with relative success to regulate the use of land and ensure sustainability, particularly in administration of agricultural land use and physical planning. The management of the use of agricultural land in Kenya is regulated by the Agriculture Act which seeks to secure proper management of land for sustained productivity. The act, among others, empowers the Minister for Agriculture to issue land conservation orders to landowners requiring adherence to certain actions to preserve agricultural land and prohibit acts which cause loss of soil fertility as well as protecting water sources within the meaning of Water Act. The Agriculture Act impairs the land-owners reasonable use of their property because they are under obligation to keep to certain rules that will ensure sustainable management of agricultural land. The Minister of Agriculture reserves the right to intervene whenever he found it necessary or expedient, for the purposes of soil conservation and maintenance of soil fertility. The public good in this case constitutes sustainable management of land that would ensure steady supply of agricultural goods. Although, the state has the right to ensure sustainable utilization and management of land through the principle of police power, its exercise of this right has repeatedly been challenged in practice. However, the regulatory potential of "police power" is scattered in several uncoordinated agencies, such as KWS, WRA, NEMA and KFS, suggesting the necessity of enhancing coordinating capacities of relevant agencies. While the police power principle has significant potential to safeguard environmental considerations in land use management, sustainable land use would benefit more from participatory land use management approaches. This is particularly so if policy choices and actions are based on democratic processes that draw largely from local experiences, knowledge, institutions and innovations. Moreover, provision of incentives, extension support and financing can enable diffusion of appropriate technologies that can integrate environmental considerations in economic and social land use choices.

The NLP provides for sustainable management of surface and underground water resources. It identifies increased human settlement on riparian reserves and cultivation within catchment areas as major challenges to water resources. To address these challenges, the policy calls upon the government to map, restore and reclaim riparian areas along lakes, rivers, swamps and other wetlands; reforest hill tops to restore aquifers and springs, and set a special fund for management and reclamation of wetlands. These policy statements provide entry points for the establish of a water fund.

The aspirations of the NLP found legislative expression in the Constitution (2010) and "new" land laws i.e. Land Act (2012),[82] Land Registration Act (2012),[83] National Land Commission Act (2012)[84] and Community Land Act (2016).[85] While the Land Act (2012) provides a mechanism for sustainable administration and management of land, the Land Registration Act (2012) has revised, consolidated and rationalized registration of title to land. The National

81 Kameri-Mbote, P. (2008) "Land Tenure and Sustainable Environmental Management in Kenya." In Okidi, C., Kameri-Mbote, P. Akech, M. Environmental Governance in Kenya: Implementing the Framework Law. East Africa Educational Publishers

82 The National Land Act 2012

83 The National Land Registration Act 2012

84 The National Land Commission Act 2012

85 The Community Land Act 2016

Land Commission (NLC) Act (2012) provides for functions and powers of the NLC and gives effect to the objects and principles of devolved government in land management and administration. The Community Land Act (2016), for its part, provides for recognition, protection and registration of Community Land rights, and management and administration of community land.

Community land consists of: (i) land lawfully registered in the name of group representatives under the provisions of any law; (ii) land lawfully transferred to a specific community by any process of law; (iii) any other land declared to be community land by an Act of Parliament; and (iv) land that is lawfully held, managed or used by specific communities as community forests, grazing areas or shrines; ancestral lands and lands traditionally occupied by hunter-gatherer communities; or lawfully held as trust land by the county governments.[86]

The NLP, the Constitution (2010) and enactment of new land laws since 2012 were widely viewed as a cure for the land question, including unproductive and unsustainable land use. However, contentions and contestations over land ownership, access and control persist. While tenure rights incorporate obligations with regard to land use, they do not articulate specific obligations to ensure sustainability and watershed management. The NLP needs to incorporate specific sustainability measures into land tenure and identify appropriate funding and governance mechanisms that will integrate environmental objectives in economic and social land use choices. Such practices should then be prioritized for uptake by land users, such as farmers.

NATIONAL LAND USE POLICY (2017)

The National Land Use Policy (NLUP) sets a framework for efficient and sustainable utilization of land resources at the national, county and community levels.[87] Not surprisingly, land and land-based resources are at significant risk from anthropogenic developments, and the anticipated or observed environmental damages are substantial. While rapid population growth is a key driver of unsustainable land use practices, its impact is amplified or attenuated by public policies and institutions. For this reason, the lack of a national policy on land use in Kenya was associated with the State's apparent inability to address land use management challenges. These challenges are manifested by haphazard developments, land and resource use conflicts, environmental degradation and underutilization of land. Over the past decades, attempts were made to address land use management issues through a multiplicity of uncoordinated policy and legal regimes that did little to unravel land management challenges. Some of the laws include: the Government Land Act, The Registration of Titles Act and the Registered Land Act which have since been repealed.

Land use denotes economic and cultural activities practiced on the land, such as agriculture, infrastructure, human settlements, rangelands, forests, national reserves and cultural sites[88]. Poor land use practices have negative impacts on water resources and ecosystems. The success of NLUP is dependent on the achievement of productive and sustainable use of land resources[89]. However, this is constrained by many challenges such as land degradation resulting from demographic pressures, cultivation on fragile ecosystems, use of inappropriate farming technologies and climate variability. The NLUP prescribes a range of interventions to

86 Ibid

87 Republic of Kenya (2017). Sessional Paper No.1 of 2017 on National Land Use Policy.

88 Ibid, P.14

89 Ibid

address these challenges. These include stakeholder' participation in environmental management, provision of appropriate incentives and application of efficient agricultural technology.

The NLUP upholds the State's right to regulate land use practices through the principle of police power. To realize this goal, the policy provides for the strengthening of the regulatory, enforcement and coordinating capacities of relevant agencies, such as National Environmental Management Authority (NEMA), Kenya Forest Services (KFS), Water Resources Authority (WRA) and Kenya Wildlife Services (KWS). Moreover, it advocates for participatory land use planning and security and equity in access to land resources. Land tenure insecurity can undermine the uptake of sustainable land use practices. However, the success of this policy also hinges on the successful implementation of the land policy. The NLUP recognizes the critical role of the county governments in land use management. The biophysical and socio-economic contexts under which environmental degradation occurs bestow enormous responsibility on county governments to prioritize sustainable land use management in development planning. The adoption of sustainable land use practices is dependent on contextual factors, that can be unraveled more effectively by county governments.

Despite providing a portfolio of specific measures for optimal and sustainable utilization of land, such as restoration of degraded lands and soil erosion control, the NLUP has many shortcomings. Land use management measures are disjointed and scattered across institutions and policy domains. This can potentially undermine implementation of proposed land use management initiatives, particularly if regulatory, enforcement and coordinating responsibilities are not clearly delineated across levels of government. Moreover, the NLUP does not sufficiently address how the significant resources required to support the implementation of proposed land use management interventions will be mobilized.

LAND ISSUES IN MWACHE DAM CATCHMENT

Land is a critical resource to sustainable development. It is a factor of production and critical feature in politics and cultural expression. Kenya's land policy pay attention to land tenure as a pathway to achieving sustainable development goals, particularly those related to social cohesion, poverty reduction, women empowerment and ecosystem management. However, land management is still entangled in conflicts over ownership, access and control. While land conflicts are pervasive virtually throughout Kenya, it manifests itself in relative intensity and breadth across regions.

Kwale County is one of the regions with deep seated land-related tensions and contestations. High incidence of landlessness, proliferation of squatter settlements and unsustainable land use practices are some of the root causes of this problem. In most parts of the Mwache Dam catchment, land is held in trust and under group ranches. Some of the trust lands have been leased out to local communities by the county government.

In Kinango subcounty of Kwale, most group ranches are non-functional leading to persistent demands to sub-divide the land among shareholders. Further effort to promote productive uses of land through adjudication and allocation of small parcels of land to individuals, mainly farmers, as private property has compounded land conflicts in the Mwache Dam catchment. Related to this is fraudulent and skewed allocation of large tracks of land to wealthy businessmen and politicians – mainly immigrants – with little or no engagement with the local community. The land conflict is further aggravated by duplication and issuance of fake title deeds. This perhaps explains why most households are not aware of their land ownership status. In recent study conducted in the Mwache Dam catchment, 82% of respondents reported that they owned the land they cultivated. However, the same study found that only 31% of respondents had title deeds for their cultivated land.

Apart from a few formally registered private lands, the tenure system in Kwale county is largely informal in which access is mainly through inheritance, with no formal documentation. About 45.7 percent of household own land without any formal documentation such as a title deed or letter of allotment, 27.1 percent have access to land through communal tenure, and only 11.4 percent through secure tenure with title deed or allotment letters. The mean size of land owned by households is 4.4 acres. Since households in the Mwache Dam catchment still lack formal land ownership, incentives to engage in productive and sustainable use of land are lacking.

In Kinango, land is largely viewed as communal asset where every member of the community has the right to use. Despite the enactment of the Community Land Act (2016) that empowers communities to register and assume the management of community lands, its implementation has been painstakingly slow. Moreover, the local communities are largely unaware of its key provisions, and ill-equipped in terms of resources and technical capacity to organize and duly register their communities for purposes of managing community lands as required by the law. As a result, neither the registration of communities nor of community lands have been done, and the county government is holding on to the trustee role in relation to community land, while communities have little to no powers with regard to ownership, access and control of those lands. This has led to unsustainable land use practices.

A further dimension to land in Kinango is that despite being the primary users of land for agricultural purposes, long-standing cultural norms have denied women and youth primary and ownership rights to land and other natural resources. Women's and youth rights relating to access to, and control of land resources remain a serious challenge. Despite this challenge, most women and youths are organized into social economic groups to strengthen their capacities to engage in development activities that directly impact on their welfare. There are 1018 registered women groups, 186 self-help groups and 709 youth groups in Kwale County. These voluntary collective actions can be used as platforms to support sustainable use of natural resources.

In western parts of the Mwache Dam catchment which fall within Taita-Taveta County, land is mostly held under group ranches which are represented by the Taita Taveta Wildlife Conservation Association (TTWCA). Prior to independence, these ranches were organized as hunting blocks, but later converted into cattle ranches. In 2004, the ranches came together to form the Taita Taveta Ranches Association (TTRA) to improve rangeland management. Subsequent engagements between the Kenya Wildlife Service (KWS) and landowners led to the establishment of wildlife conservancies to enable further income generation through tourism activities associated with the Tsavo East and West National Parks. This led to the conversion of ranchers to wildlife conservancies. As a result, TTWCA was established in 2012 to support the newly developed conservancies and other ranches to enhance sustainable management and utilization of natural resources across the greater Tsavo ecosystem. Currently, seven ranches have put their land under conservation management to form the Tsavo Conservancy. A large portion of this 100,000-ha area falls within the upper part of the Mwache Dam catchment.

A small portion of the catchment falls within formally protected areas. The northwest of the catchment is a protected area within the Tsavo East National Park. Other protected areas include parts of Kasigau Forest Reserve which falls inside the upper western part of the catchment, and Mwache Forest Reserve falls within the lower reaches of the catchment. However, the forest reserves have been heavily encroached by agriculture and settlement.

NATIONAL ENVIRONMENT POLICY 2013

The environment is a vital component in the quest for sustainable development. It delivers resources that sustain production systems. In Kenya, environmental resources contribute directly and indirectly to the local and national economy through revenue generation and wealth creation in such productive sectors as agriculture, fisheries, livestock, water, energy, forestry, trade, tourism and industry. By the same token, the environment is the medium into which wastes from production and consumptive processes are absorbed, often with deleterious consequences.

The national environment policy seeks to improve quality of life for present and future generations through sustainable management and use of the environment and natural resources.[90] Specifically, the national environment policy (NEP) provides a framework for (i) an integrated approach to planning and sustainable management of Kenya's environment and natural resources; (ii) strengthening the legal and institutional framework for good governance, effective coordination and management of the environment and natural resources; (iii) ensuring sustainable management of the environment and natural resources for national economic growth and improved livelihoods; (iv) promoting and supporting research and capacity development and the use of innovative environmental management tools such as incentives, and Payment for Environmental Services (PES); (v) promoting and enhancing cooperation, collaboration, synergy, partnerships and participation in the protection, conservation, sustainable management of the environment and natural resources; (vi) ensuring inclusion of cross-cutting and emerging issues such as poverty reduction, gender, disability, HIV&AIDS and other diseases in the management of the environment and natural resources; and (vii) promoting domestication, coordination and maximisation of benefits from Strategic Multilateral Environmental Agreements (MEAs).

The national environment policy gives recognition to Kenya's critical ecosystems and natural resources, such as forests, freshwaters, wetlands, coastal and marine, mountains, arid, semi-arid and spectacularly diverse wildlife populations. Within these ecosystems are critical natural and cultural heritage resources which support rich biodiversity and provide natural capital for economic development and livelihood support. With regard to the conservation and management of ecosystems and sustainable use of natural resources, the NEP proposes a range of measures, such as (i) developing and implementing a national strategy for the rehabilitation and restoration of degraded forest ecosystems and water catchment areas with active participation of communities; (ii) encouraging development and implementation of appropriate forestry-based investment programs and projects, and involving and empowering communities in forest ecosystem management; (iii) developing and implementing integrated freshwater and wetland resources management strategies and action plans; (iv) promoting and institutionalizing payment for environmental services schemes to support catchment protection and conservation; (v) promoting sustainable use of freshwater and wetland resources and conservation of river and lake ecosystems through development and implementation of river basin management plans; and (vi) harmonizing and coordinating the roles of various regulatory agencies charged with the management of freshwater and wetland

[90] National Environment Policy (2013), p.8

ecosystems. As such, the policy has strong relevance to watershed management. However, there is inadequate framework for payment for environmental services schemes, and limited recognition of the value and benefits that accrue from ecological infrastructure. Naturally functioning ecosystems confer various benefits in the form of provisioning, regulating, cultural and habitat/supporting goods and services.[91] While water catchments are attractive because of the abundance of water resources; they are vulnerable to anthropological developments. Strengthening ecological infrastructure is an essential dimension in securing reliability of water supply in face of mounting human pressures.

LAND RECLAMATION POLICY (2013)

The land reclamation policy seeks to integrate national interests and stakeholder participation, including those whose actions affect and/or are affected by land and water degradation, and consolidate and coordinate all reclamation initiatives. Despite recognizing the impact of land degradation on water resources and the need for sustainable land use systems and water security, the land reclamation policy does offer any incentives to promote voluntary action towards restoration and rehabilitation of degraded lands. Due to the strong nexus between land degradation and water scarcity, and thus the potential of nature-based solutions in land reclamation especially in arid and semi-arid lands (ASALs), the policy should give more emphasis to incentive arrangements for "natural infrastructure" in land management. However, its rationale acknowledges the need to ensure appropriate reclamation systems for different agro-ecological zones that increase the stock of productive land resources; rainwater harvesting and storage; and surface and groundwater resources storage, in order to address challenges of food insecurity, pasture and water shortage. The policy commits the government to, *inter alia*: (i) promote mobilization of resources for reclamation of ASALs and wastelands with increased investment in rainwater harvesting and storage; (ii) increase public investment in the land reclamation sub-sector to at least 1% of the annual national budget; and (iii) create an enabling environment for increased private sector investment, primarily through Public-Private-Partnerships (PPPs) arrangements; and (iv) promote extension and training services on land reclamation to ensure creation of the necessary capacity in terms of qualified personnel.

KEY LEGISLATION

THE WATER ACT, 2016

The Water Act (2016) is framed to align the water sector with the devolved governance framework of the Constitution (2010). The Act contains an overarching provision requiring its administration or application to be guided by relevant constitutional provisions.[92] These include Article 10 on the national values and principles of governance; Article 43 outlining economic and social rights in the Bill of Rights; Article 60 on equitable, efficient, productive and sustainable management of land resources; and Article 232 on the values and principles of the public service. The Water Act contains key salient features which are of relevance to the establishment of the Mombasa Water Fund. These are discussed below.

---

[91] Fisher, B. & Christie, M. (2010). Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation. In Kumar P (ed) TEEB: the economics of ecosystems and biodiversity. Ecological and Economic Foundations, Earth Scan, London. Chapter 1, p 1–40

[92] Section 4 of the Water Act (2016).

Ownership of Water resources

The Constitution of Kenya (2010) vests natural resources in the people of Kenya. Water resources, including rivers, lakes and other water bodies as defined by an Act of Parliament are included in the definition of public land.[93] According to the Constitution, "all land in Kenya belongs to the people of Kenya collectively as a nation, as communities and as individuals" and consequently the people of Kenya essentially own the country's water resources.[94]

The Water Act (2016) makes it clear that while the state, and more specifically national government, is the custodian of resources, it holds them in trust for the people of Kenya.[95] This has some interesting implications to water resource governance. Firstly, defining rivers, lakes and other water bodies as public land puts them under the mandate of the National Land Commission (NLC). Arguably, this provides a framework for sustainable governance of all-natural resources, including water. While the Water Act (2016) contains no explicit recognition of this oversight role of the NLC, it is replete with references to other land laws including the Land Act[96] and the Community Land Act.[97] Further, in recognition of the central nexus between land and water resources, the Act provides for representation of the Principal Secretary responsible for land or his/her representative in the membership of the Water Resources Authority Management Board. Interestingly, the Water Act (2016) includes a provision subordinating its provisions pertaining to community land to the Community Land Act.[98]

Devolved Governance Framework for Water Resources

Among the fundamental governance changes introduced by the 2010 Constitution was the creation of a devolved government, with clear separation of roles between the national and county governments. Kenya's devolved government is based on the division of the country into 47 geographical units referred to as counties. In accordance with the concept of integrated water resources management, Kenya is divided into six main river basins: Lake Victoria North, Lake Victoria South; Rift Valley Basin; Athi River Basin (in which the study area is located); Tana River Basin; and Ewaso Ngiro Basin. These basins traverse the various county boundaries. In relation to devolution of water governance, the Constitution, in its fourth schedule, identifies and sets out the role of the national government to protect the environment and natural resources, including water resources, with the objective of "establishing a durable and sustainable system of development". [99] This specifically encompasses the management of national public works, water protection, securing sufficient residual water, hydraulic engineering and safety of dams. [100] The county government is responsible for the implementation of national water policy and the management of county public works and services, which include storm water management systems and the provision of water and sanitation services.

The Water Act (2016) clarifies the effect of a devolved governance framework for water resources. During stakeholder meetings preceding the enactment of the Act, counties raised the possibility of hosting water resources, to charge other counties for the use of the water

93 Article 62(1)(i) of the Constitution of Kenya (2010).
94 Article 61 of the Constitution of Kenya (2010).
95 Section 5 of the Water Act (2016).
96 Section 8(4) of the Water Act (2016).
97 Section 138 of the Water Act (2016).
98 Ibid.
99 Fourth Schedule Part 1(22) of the Constitution of Kenya (2010)
100 Ibid.

sourced from their county - for example, Murang'a County's contention with respect to water supply from Ndakaini Dam to Nairobi County. Section 6 of the Water Act (2016) debunks this notion by assigning the Water Resources Authority the role of regulating the management and use of water resources as an agent of the national government. Water basins in Kenya, as in other jurisdictions, cut across various county boundaries and thus the vesting of ownership in specific counties would have resulted in the need for complex inter-county arrangements for sharing of water resources. A legal framework for inter-county water supply arrangements might have been convenient for the operations of the proposed Mombasa Water Fund. Nevertheless, article 189 of the Constitution of Kenya 2010 allows counties to develop institutional arrangements with other counties or the national government on inter-jurisdictional issues of common concern. This is important because the flow of water across borders often is a complex matter, which may require special institutional arrangements that would stretch across the jurisdictions.

The Water Act (2016) also includes any water works that relate to cross-cutting water resources or works whose objective is to serve national government in the definition of **national public water works**. This further clarifies the issue of ownership and management of water resources.[101] In the fourth schedule of the Constitution, public works constitute a function of the national government in contrast with **county public works**, which are a function of county governments.[102] The Act also grants wide-ranging powers to the national government in relation to public water works including powers to acquire land required for national water infrastructure.

Right to water

The Water Act (2016), in alignment with the Constitution, explicitly recognizes the fundamental right of every person in Kenya to clean and safe water in adequate quantities and to reasonable standards of sanitation.[103] Further, the Act clearly stipulates that the role of regulating the management and use of water resources lies with the national government through its agent, the Water Resources Authority.[104] Apart from recognizing the right to water and sanitation, the Water Act (2016) attempts to flesh out some normative content constituting the government's obligation relating to the progressive realization of the right. For instance, the Act requires the Cabinet Secretary responsible for water to prepare a five-year National Water Services Strategy which will include the plans for the progressive realization of this right to water and sanitation to all. The Water Services Regulatory Board (WASREB) is also obliged to make regulations, which should among other issues, address the progressive realization of the right to water services.[105] In addition, the Act requires that Water Service Providers (WSPs) that hold county or national public assets, refrain from paying dividends or making any other payments as long as the universal rights of access to safe and clean water have not been achieved in the designated service areas.[106]

Linking of water rights to land rights

The primary mode of granting water rights under the Act is through permits from the Water Resources Authority (WRA). However, the Water Act (2016) recognizes the concept of

[101] Section 8, Water Act (2016).
[102] Fourth Schedule Section 19 of the Constitution of Kenya (2010).
[103] Section 63 of the Water Act (2016).
[104] Section 6 of the Water Act (2016).
[105] Section 72(1)(n) of the Water Act (2016).
[106] Section 131(3) of the Water Act (2016).

public trusteeship by vesting the ownership of water in citizens. The state, through the national government, plays the role of administration of the water resources.[107] This is consistent with the Constitution. The Water Act (2016) introduces some changes that could have important ramifications on requirements for water permits and exemptions. For instance, the Water Act (2016) links permits to land or undertakings on land. For instance, the Water Act (2016) links permits to land or undertakings on land. This approach to water governance has been criticized on the basis that groundwater is often the main source of drinking water for most people, and thus tying water rights to land rights does not contribute to a social perspective to water or to the realization of the human right to water.[108] It has been argued that in fact, this linkage serves to privatize water rights and in so doing, limit the right to acquire such rights to those who have rights to land or the potential to acquire these rights.[109] Poor rural communities end up disadvantaged because they do not often have title to the community land to which their water resources are appurtenant. They can thus not acquire water rights under the Act. Communities in Mwache Dam catchment are predominantly farmers, and would therefore need to hold water rights in respect of any water that is abstracted from natural sources, such as streams and springs, to supply irrigation needs.

THE LAND ACT, 2012

The Land Act (2012) was enacted to ameliorate land problems that were caused by multiple legislations relating to land administration, use and management in Kenya. The Act provides for sustainable administration and management of land. Absence of land tenure is arguably a major constraint to sustainable land management. The Act provides for opportunity that can be used to address challenges with land tenure. The Act establishes freehold tenure, leasehold tenure, and customary land rights. Under the Land Act (2012). Title to land may be acquired through allocation, land adjudication process, compulsory acquisition, prescription, settlement programmes, transmissions, transfers and long-term leases exceeding twenty-one years. These provisions can be used to address land tenure problems in Mwache Dam catchment.

Similarly, the Land Act (2012) can be used to promote watershed conservation. Under the Act, the National Land Commission can implement settlement programmes to provide access to land for human settlements and livelihood benefits on behalf of the county and national governments. The settlement programme includes provision of access to land to squatters; persons displaced by development projects, internal conflicts or conservation programmes. Section 8(4) of the Water Act (2016) refers to the Land Act. This provision states that: "Subject to the Land Act, 2012, land required for national public water works may be acquired in any manner provided by law for the acquisition of land for public purposes". This is in the context of national public water works where public interest would be the guiding principle in the acquisition of such land. The acquisition of land for public purposes can also be done in the interest of environmental conservation.

[107] Section 9 of the Water Act (2016).

[108] Cullet, P (2006) "Water law reforms – analysis of recent developments" 48(2) Journal of the Indian Law Institute 206-231.

[109] Mumma, A (2008) "Kenya's New Water Law: An Analysis of the Implications for the Rural Poor" in M Giordano, BV Koppen & J Butterworth (eds) Community-based water law and water resource management reform in developing countries.

THE COMMUNITY LAND ACT, 2016

Article 63 of the Constitution provides that community land shall vest in and be held by communities identified on the basis of ethnicity, culture or similar community of interest. The Constitution further provides that parliament shall enact legislation to give effect to this article. The Community Land Act, 2016 gives effect to constitutional recognition that community lands exist as a lawful class of property. This law gives effect to constitutional recognition that rural communities own half or more of the national area of Kenya under customary tenure. The Act lays out procedures through which communities may secure formal entitlement to these lands under collective title.

The right for communities to hold some or all of their lands in common is explicit in the law. Such communal rights and thus the lands they refer to are equally protected with individual and family rights. The community may under Section 13 (3) of the Act reserve 'special purpose areas', including for community conservation, cultural site protection, farming, settlement, urban development, or 'any other purpose'. Additionally, they are instructed to use and manage natural resources 'sustainably and productively'. This is followed by clauses enabling communities to transfer rights to investors for the use and occupation of their lands.[110] This is subject to community assembly agreement. The agreement relating to investment in community land shall be made after a free, open consultative process and shall contain provisions on the environmental, social, cultural and economic impact assessment.

Communal rights are potentially undermined by some provisions which appear to conflate communal use and public use and in a manner that, when read with other clauses, could result in exclusion of some common properties from entitlement. This includes above-mentioned provisions that the national and county government may earmark community lands 'to upgrade public interest'.[111] Such opacities could potentially deprive communities of lands they have voluntarily made available for schools and clinics and other lands intentionally left unoccupied for holding livestock, markets and other community functions. Even traditionally-owned and used waterpoints, used for dry season cropping and grazing, could fall to the state in light of the expansive way in which water is earmarked as a public asset. There is also a likelihood that the state may initiate land management and conservation interventions to protect reserved lands and buffer zones.

The Community Land Act (2016) provides that the management of community land shall be subject to national and county government laws and policies in relation to, among other matters, water protection, securing sufficient residual water, hydraulic engineering and dam safety.[112] A broad interpretation of this provision implies that the Community Land Act is subordinate to the provisions of the Water Act (2016), in so far as most, if not all, the provisions of the latter Act are ultimately intended to ensure water protection, secure sufficient residual water, hydraulic engineering and safety of dams.

The Act explicitly recognizes the existence of community land rights as demonstrated by its subordination of the application of its provisions to any written laws relating to community land.[113] Arguably, the import of this provision is to limit the extent to which the Water Act

---

[110] Section 36 o Benefit sharing.
[111] Article 40 (3) of the Constitution.
[112] Section 38(2)(c) of the Community Land Act (2016).
[113] Section 138 of the Water Act (2016).

(2016), including its provisions relating to water permits, are applicable to community landowners.

THE NATIONAL LAND COMMISSION ACT, 2012

This Act contains provisions on the functions and powers of the National Land Commission, qualifications and procedures for appointments to the Commission; and gives effect to the objects and principles of devolved government in land management and administration. It is important to note that the Act defines community to mean a clearly defined group of users of land identified on the basis of ethnicity, culture or similar community of interest as provided under Article 63(1) of the Constitution, which holds a set of clearly defined rights and obligations over land and land-based resources.[114]

This is of importance to this study given that part of the study area may embody community rights. Additionally, the Act under section 3 sets out the object and purpose of this statute to provide—

(a) for the management and administration of land in accordance with the principles of land policy set out in Article 60 of the Constitution and the national land policy;

(d) for a linkage between the Commission, county governments and other institutions dealing with land and land related resources.

Water is a land related resource and therefore this Act is relevant to water resources management and development.

ENVIRONMENT MANAGEMENT AND COORDINATION ACT, 2015

This Act provides the overall legal and institutional framework for the management of the environment (including water resources) in Kenya.

Protection and sustainable use of water resources and their catchments

Section 42 of part V of the Act provides for the protection of rivers, lakes and wetlands. Among other things, it prohibits the alteration, disturbance and/or drainage of water sources.

Pollution prevention and control

The Act empowers the Minister to declare 'protected area status' to a water resource and impose restrictions that would protect the resource, and issue regulations, guidelines and / or standards; including pollution prevention and control as well as sustainable use of water resources and their sources. Section 47 of part V of the Act mandates the National Environment Management Authority (NEMA), in consultation with relevant lead agencies, such as WRA, KWS, KFS, and National Government Administration, to issue guidelines and prescribe measures that will protect water catchment areas. These provisions present a good place for anchoring water fund mechanisms within existing legal framework.

[114] http://kenyalaw.org/kl/fileadmin/pdfdownloads/Acts/National_Land_Commission_Act___No_5_of_2012_.pdf (accessed 11 April 2021).

Measurement of the value of water-related ecosystem services

Under section 50 Part V, the Authority is mandated to measure the value of unexploited natural resources in terms of watershed protection, influences on climate, cultural and aesthetic value among others.

Section 54 (1) states, "The Minister may in consultation with the relevant lead agencies, by notice in the Gazette, declare any area of the land, sea, lake or river to be a protected natural environment for the purpose of promoting and preserving specific ecological processes, natural environment systems, natural beauty or species of indigenous wildlife or the preservation of biological diversity in general". Furthermore, section 2 mandates the Authority, in consultation with the relevant lead agencies, to issue guidelines and prescribe measures for the protection and management of protected natural environments.

Fiscal incentives for water conservation and enhancement of ecosystem services

Section 57(2)(d) provides for user fees to ensure that those who use environmental resources pay proper value for the utilization of such resources. Although, this requirement does not place an obligation on water users to pay for catchment protection and conservation, it provides a basis to build upon for possible water fund mechanism.

Setting of water quality standard

In Section 71 of Part VIII, the Standards and Enforcement Review Committee is obligated to recommend minimum water quality standards for all waters of Kenya for different uses; including drinking, industrial, agricultural, recreational, fisheries and wildlife, and any other prescribed water use to the Authority (i.e. NEMA). The Committee is also meant to prepare and recommend guidelines or regulations for the preservation of fishing and aquatic areas, water sources and reservoirs, and other areas where water may need special protection.

Licensing of water use

The Act prohibits water pollution and prescribes a penalty for such offences. It has also put in place a licensing system for effluent discharges.

The sections highlighted above provide regulations geared towards the protection, quality maintenance and management of the environment, including water resources and their catchments. Its effective enforcement should enhance freshwater ecosystems services and contribute towards poverty reduction by ensuring that good water quality and sufficient quantity is sustained. The provisions discussed above present a good place for anchoring water fund mechanisms for the management of water catchment areas.

COUNTY GOVERNMENT ACT, 2012

The devolved framework under the Constitution of Kenya (2010) has wide-ranging implications for the water sector. The Fourth Schedule outlines the distribution of functions between the national government and the county governments. Sections 2 and 11 of the Fourth Schedule of the Constitution of Kenya 2010 stipulate that the functions and powers of the county governments include water and sanitation services, storm water management in 'built-up areas', and solid waste management. Section 22 of the Fourth Schedule places the responsibility for developing policy and regulation for water resource management with the national government, while counties are responsible for implementing these policies. Article 185 of the Constitution of Kenya 2010 provides for the county assembly to make any "laws that are necessary for or incidental to, the effective performance of the functions and exercise of the powers of the county government under the Fourth Schedule of the Constitution of Kenya 2010."

Devolved government is prevised under chapter eleven of the Constitution and the County Government Act gives effect to this. It provides for county governments' powers, functions and responsibilities to deliver services. In the context of water, the Act has salient provisions as set our below:

Planning and budgeting

The Act requires county plans based on the functions specified in the Constitution and budgeting to achieve the progressive realization of the rights guaranteed under the Constitution of Kenya (2010). County plans include: integrated development plan; sector plans for the provision of water, sanitation and solid waste management services; spatial plan; and urban plans as provided for under the Urban Areas and Cities Act of 2011.

Tariffs

The Act gives county governments the mandate to establish tariff policies for services delivered within the county, such as water services. Section 120 of the County Government Act outlines specific guidelines for establishing tariffs, with a strong focus on equity and financial and environmental sustainability. For instance, the amount individual users are required to pay for services should be in proportion to their use of that service.

Public-private partnerships

Section 6 of the Act allows county governments to enter into partnerships with any public or private organization for any work, service or function within its area of jurisdiction. This implies that county governments can delegate the management and delivery of specific services to the private sector or a public entity. This provides an entry point for anchoring water fund mechanisms.

Monitoring and reporting

Section 47 assigns responsibility for a performance management plan to the County Executive Committee to evaluate county public services and the implementation of county policies. The national government must provide support to county governments to enable them to perform their functions, including performance and capacity assessments. If assessments demonstrate any inability to perform functions, the cabinet secretary can call for national intervention, even performing the functions with approval of Parliament.

Decentralized urban services

Under Section 48, the functions and provisions of services within each county are decentralized to the urban areas and cities within the county established in accordance with the Urban Areas and Cities Act of 2011. County governments should therefore be aware of the specific duties and responsibilities on urban water and sanitation services.

Intergovernmental coordination

Section 54 requires the establishment of a County Intergovernmental Forum that includes the heads of all national departments rendering services in the county. This forum provides a critical platform for coordination between county and national government.

URBAN AREAS AND CITIES ACT, 2011

The Urban Areas and Cities Act of 2011 provides for the definition of and principles of governance and management for urban areas and cities in each county. In the context of water, the Act has salient provisions as set our below:

Governance and management for urban areas

Section 12 of the Urban Areas and Cities Act of 2011 states that: "The management of a city or a municipality shall be vested in the county government and administered on its behalf by a board with the mandate to develop and adopt policies, plans, strategies and programs, and may set targets for delivery of services. The Board serve as the agents responsible for urban water, sanitation, sewerage, and solid waste management services."

Integrated development planning

Section 36 of the Urban Areas and Cities Act of 2011 states that "every city and municipality shall operate within the framework of integrated development planning, including delivery of basic water and solid waste management services".

THE FOREST CONSERVATION AND MANAGEMENT ACT, 2016

The Forest Conservation and Management Act gives effect to article 69 of the Constitution of Kenya (2010) and provides for the development and sustainable management, including conservation and rational utilization, of all forest resources. The Act establishes the Kenya Forest Service.[115] Under section 8 of the Act, the functions of the Kenya Forest Service include the management of water catchment areas in relation to soil and water conservation, carbon sequestration and other environmental services in collaboration with relevant stakeholders. Additionally, management of water in indigenous forests is provided for in Section 42 is to the effect that "*all indigenous forests and woodlands shall be managed on a sustainable basis for purposes of conservation of water, soil and biodiversity.*"

WILDLIFE CONSERVATION AND MANAGEMENT ACT 2013

The Wildlife Act provides for wildlife protection, conservation and management in Kenya. The Act also designates national parks, national reserves, and local sanctuaries to facilitate wildlife conservation and management and further provides for protection and management of watersheds as protected areas.

Additionally, section 28 provides that no provision of the Act and no rights or entitlements conferred and granted under the Act shall, wherever appropriate operate to exempt a person from compliance with the provisions of the Water Act, 2002 concerning the right to the use of water from any water resource, reservoir or point. Given that the Water Act 2002, was repealed and replaced by the Water Act 2016, this would mean that the provisions under the Water Act supersede the provisions of the Wildlife Conservation and Management Act 2013 in so far as compliance in the context of water is concerned.

[115] http://kenyalaw.org/kl/fileadmin/pdfdownloads/Acts/ForestConservationandManagementActNo34of2016.pdf (accessed 11 April 2021)

COUNTY ACTS

County governments are required to develop their own policies and legislation not inconsistent with national policies and legislation to establish county-based institutions and procedures to enhance delivery of services in regard to water and sanitation, storm water drainage, soil and water conservation and environmental conservation. Mombasa, Kilifi and Kwale Counties have passed their Water Acts. With the exception of the Mombasa County Water Act, which only provides for water and sewerage services and storm water management, other Acts have provisions for soil, water and environmental conservation.

The Mombasa County Water and Sewerage Services Act, 2016

Mombasa County Water and Sewerage Act (2016) provides for a legal and institutional framework for provision of water and sewerage services; and for mechanisms of ensuring high quality services to citizens, and commercial viability of the water service provider. Specifically, the Act seeks to establish and maintain a financially sustainable mechanism for the delivery of water and sanitation services, enhance and expand the provision of water and sanitation services, secure and sustain progressive realization of human rights to water and sanitation, provide incentive for private sector contribution in the service provision and in investment in infrastructure development. For purposes of this study two salient features will be discussed:

- Establishment of Mombasa Water and Sewerage Services Corporation

Section 8 provides for the establishment of the Mombasa Water and Sewerage Services Corporation, which is required to "acquire, take over and assume all responsibility for water service provision in the County of Mombasa as determined under the Constitution of Kenya". From this provision the Corporation is mandated to develop and manage works for water conservation.

- Public Private Partnership

The Act stipulates under Section 20 that the Board of the Corporation may pursue public private partnership options for development of water services infrastructure. This provision provides a leeway for private sector participation in water and sanitation services.

The Kwale County Forest Conservation and Management Act, 2017

Kwale County has enacted a law to provide for the sustainable management of Kwale County forests. The Act is applicable to county, community and private forests. There are two unique provisions which have a bearing on water catchment resource management. These include:

- Integrated Ecosystem Approach

Section 16 provides that: "All forests shall be managed in accordance with the integrated ecosystem approach that takes into consideration the wood and non-wood resources, the environmental services and the socio-economic benefits provided by the forests".

- Purpose of Managing County Forests

Section 18 provides that: "The County Executive Member in charge of forestry shall be responsible for the conservation, utilization, protection and sustainable management of forests and forest resources belonging to the county for the purposes of conservation of water, soil and biodiversity, county cultural and religious heritage, riverine and riverbank protection, and carbon sequestration and other environmental services and recreation and tourism." The Act provides for community participation in the management of county forests. A registered community group adjacent to a county forest may apply to the county government for permission to participate in the conservation and management of a county forest. This provision provides a leeway for organized groups, such as WRUAs or CFAs to engage in forest conservation initiatives. The Act requires owners of forests on private land to ensure sustainable conservation, utilization, protection of forests and forest resources on their land for the purposes of conservation of water, soil and biodiversity.

Kwale County Water and Sanitation Services Act (2020)

The Act provides for a framework for provision of water and sanitation services, and implementation of specific national government policies on natural resources and environmental conservation, including soil and water conservation. Specifically, the Act seeks to ensure equitable and continuous access to clean and safe water; promote soil and water conservation; promote water catchment conservation and protection; provide for the development and management of county water services public works; provide for coordination and regulation of county water and sanitation public works; ensure effective and efficient provision of water and sanitation services; promote effective and efficient management of storm water in built up areas; enhance sustainable management of water resources; and promote interagency collaboration and public participation in water resource development and management.

Kwale County Water and Sanitation Services Act provides for the establishment of the establishment and operation of Water Services Providers (WSPs) with a responsibility for the provision of water and sewerage services. The operations and performance by a county WSP is subject to license issued by WASREB. The County WSP, with the approval of the County Executive Committee Member (CECM) for responsible for finance, and CECM responsible for Water Services, may enter into public private partnership in order to effectively carry out its functions in accordance with the Public Private Partnership Act. This provision provides a window for engagement with private and public sector entities in water service provision.

While the tariffs for water and sanitation services are subject to regulations as set out by WASREB, the county government may in appropriate cases provide financial assistance to enable WSPs to meet a portion of their operation and maintenance costs. Arguably, the county government can use this window to set aside some resources for catchment conservation, particularly if a county WSP is operating or contributing to a water fund to enhance their performance by reducing water treatment costs and guarantee regular supplies.

KENYA WATER TOWERS BILL, 2019

This bill proposes to establish the Kenya Water Towers Authority (Section 4 (1)) to replace the Kenya Water Tower Agency (KWTA) established under the State Corporations Act. With the exception of a few changes, the overall functions of the Authority have been maintained as they were for the predecessor, KWTA. The objects and purposes of the proposed Kenya Water Tower Act are:

a) To provide an effective legal framework for the sustainable management of water towers for the purpose of fulfilling Articles 26, 42 and 43 of the Constitution;

b) To provide an institutional framework for the effective coordination of the various actors involved in the management of water towers;

c) To promote public awareness about the need for the protection, rehabilitation, conservation, and sustainable management of water towers.

Schedule 2 of the Bill has listed the Chyulu and Shimba Hills, which form the recharge catchment areas of the Mombasa City Water supply sources, among the other 18 water towers. Additionally, the Bill provides that the Authority shall, in consultation with the national and county Government, promote public awareness about the need for the protection, rehabilitation, conservation, and sustainable management of water towers through comprehensive nationwide educational and information campaigns and shall collaborate with relevant stakeholders to ensure the involvement and participation of individuals and groups affected by adverse use and management of water towers.

STRATEGIES AND PLANS

NATIONAL ENVIRONMENT ACTION PLAN (2018-2024)

The National Environment Action Plan (NEAP 2018-2024) is a strategic planning framework within which environment and sustainable development issues are identified and prioritized. It is a demand-driven process, based on local participation, which aims to mainstream environment into national, county and sectoral development planning. The NEAP provides the basis for managing, monitoring, and evaluating a plan of action.

Kenya developed its first National Environment Action Plan in 1994. This was fundamental to environmental management and resulted into the enactment of the Environment Management and Coordination Act (EMCA) No.8 of 1999, and the establishment of the National Environment Management Authority (NEMA). EMCA provided for the integration of Environment into national policies, plans and programs and a statutory provision for development of a National Environment Action Plan after every five years.

The overall goal of the National Environment Action Plan (2018-2024) is to attain environmental stewardship, environmental sustainability and maintain a transformational and participatory approach to natural resource use and environmental management by 2024.[116] As a result, the NEAP is designed around four strategic goals with result areas and actions. The first strategic goal on environmental stewardship seeks to protect and nurture natural resources through risk identification and management. The sectors covered under this goal are land and soils; climate change and climate variability; water, water resources and pollution; wildlife, biodiversity and ecosystems; and forest woodlands and bush lands. Among the strategic result areas include improved integrity of biodiversity and ecosystems for increased ecosystem services and goods. The proposed strategic actions to achieve environmental stewardship, among others include: (i) upscaling forest conservation measures to restore degraded forest landscape and ecosystems; (ii) developing and strengthening the concept and application of 'natural infrastructure' and landscape planning and management; (iii) Improving forest cover through restoration of degraded forests and plantations establishment; (iv) designing and implementing projects on restoration of degraded catchments including water towers, wetlands and riparian zones; and (v) developing comprehensive river basin management programs focusing on catchment rehabilitation to stem sediment yields from the catchments.

[116] National Environment Action Plan (2018-24)

The second strategic goal on environmental sustainability seeks to promote prudent use of the environment and natural resources for present and future generations. This goal analyses the key drivers of environmental change arising from the use of environmental goods and services. The sectors covered under this goal include agriculture, livestock and fisheries; settlement, urbanization and transport; health, sanitation and waste; energy, mining and industrialization; trade and tourism; and environmental hazards and disasters. The intended strategic result areas for this goal include upscaling sustainability in agriculture and mainstreaming of disaster risk reduction and preparedness.

The third strategic goal on environmental transformation strives for a strategy to obtain desired transformation through optimizing the value of natural resources and environment. It covers aspects related to services and enabling environments such as environmental education, information and communication; research, technology and innovation; governance compliance and enforcement; environment and climate change finance; and public-private partnerships. Some of the intended strategic result areas for this goal include among others: enhanced environment management through transformative research, technology development and innovation; upscaling and strengthening of environmental governance, compliance and enforcement; and upscaling and strengthening of public-private partnerships in environmental management. The NEAP gives recognition to public-private partnerships and seeks to strengthen the concept in water sector. Despite the enabling environment in terms of legislation, policy and regulations, public-private partnerships in the environment and water sector have not taken root in the country. Collaboration between public and private organizations is still not considered public-private partnerships, especially when they are short-term with neither direct commercial benefit to the private sector nor strong public service. While some organizations have corporate social responsibilities and partnerships for environmental initiatives such as tree planting and cleaning of environment, these are often one-off engagements which barely meet the threshold of public-private partnerships.

The fourth strategic goal focuses on the devolution of environmental management. It covers the strategic actions generated through county and national engagements and the readiness to implement these at the subnational and national levels. This is intended to give opportunity for participatory management of the environment and natural resources, and ensure access to environmental benefits. Some of the intended result areas for this strategic goal include the prioritization of environment issues at county levels and upscaling these to the national level for implementation.

THE NATIONAL WATER MASTER PLAN 2030 (NWMP)

The National Water Master Plan 2030 (NWMP) is Kenya's water resources development and management blueprint. It assessed and evaluated the national water demands for the year 2010 and projected demands for 2030 and 2050. The projection for 2030 was intended to formulate the NWMP, and that for 2050 to assess future vulnerability of water resources in the face of climate change.

The National Water Master Plan 2030 covers all six river basins in Kenya. For each basin, it provides information related to water resources, water demands, high-level water allocations, economic evaluations of proposed interventions and implementation for the period 2010 – 2030. Moreover, the NWMP 2030 presents development plans related to water supply, sanitation, irrigation, hydropower and water resources as well as plans for catchment management, hydrometeorological monitoring, floods, droughts and environmental management. The relevant plans for the Athi River Basin are described below.

According to the NWMP 2030, the country's renewable water resources per capita increased from 647 m^3 in 1997 to 1093 m^3 in 2010. However due to rapid population growth, it is expected to decrease to 475 m^3 in 2030. This suggests the urgency for protection and conservation of water catchments and sustainable use of water resources. The NWMP 2030 also provides a framework for expansion of infrastructure for national water storage capacity.

The national master plan is informed by comprehensive data and sound information. Accurate information is required to determine the quantity of water resource availability, establish its location, estimate future demand, and design management options. However, the preparation of NWMP 2030 was constrained by limited data.[117] Any planning presupposes the availability of sufficient data of good quality for analysis and synthesis. Deficiency in relevant data is one of the basic challenges in water resources planning. This design study seeks to address this gap in the Mwache Dam catchment.

ATHI INTEGRATED WATER RESOURCES MANAGEMENT AND DEVELOPMENT PLAN

The Athi Integrated Water Resources Management and Development Plan provides a clear pathway for the sustainable utilization and development of the water resources of the Athi Basin.[118] It describes the current status of the basin, creates a shared vision for future development in the basin, and prioritizes key strategic interventions for effective development and management of the basin's water resources. The vision for the sustainable development of the Athi Basin seeks to attain "a w*ell-managed and protected river basin characterized by good governance, sustainable socio-economic development for all, and a clean, safe and water secure environment, which enhances quality of life from the Aberdares to the Indian Ocean.*[119]

The Athi Basin covers an area of 66 559 km^2 (i.e. about 11% of Kenya's land surface) and hosts Nairobi and Mombasa, the two largest cities in Kenya. This implies that rapidly growing economies and urban populations are inflicting serious limitations on water availability and adequacy in the Basin, ultimately undermining economic development and ecosystems. The Plan has identified and prioritized specific challenges to water resources in the Athi Basin. These include biophysical issues such as climate change, poor land use and watershed planning and management, and biodiversity loss; socio-economic issues such as burgeoning population growth, low awareness of environmental issues and high poverty levels, water resources availability, management and development issues such as inadequate protection and conservation of surface and ground water resources, inadequate water harvesting and storage, unsustainable and inequitable water allocation and use, and inadequate institutional arrangements.[120] The potential overall effects of the above pressures on water resources under a business-as-usual (BAU) scenario (i.e. without any management interventions) will entail reduced water availability amid surging demand, primarily due to loss of vegetation in the catchment. Ten percent reduction of vegetation cover is projected by 2040 due deforestation and overgrazing.[121] The planned development of water storage and irrigation

[117] JICA, 2013
[118] Athi Integrated Water Resources Management and Development Plan, p.1
[119] Ibid, p.2
[120] Ibid, p.viii
[121] Ibid, p.142

infrastructure in the basin contribute to this.[122] Accordingly, a Sustainable Development scenario was developed to demonstrate a balanced water resources development which limits environmental and social impacts. This scenario attempts to limit water development in environmentally sensitive areas, and assumes reforestation and reduction in future urban water demands through demand management measures. Subsequently, ten strategic areas were formulated for the Athi Basin to address a range of water related issues and challenges. These include: catchment management, water resources protection, groundwater management, water quality management, climate change adaptation, flood and drought management, hydrometeorological monitoring, water resources development, strengthened institutional frameworks and enabling environment to support effective institutions.[123] Of particular importance, the implementation of the Athi Basin Plan will require strengthened coordination between different county governments and relevant governing bodies and institutions. Additionally, it emphasized the importance of innovative financing in the implementation of the proposed management interventions. However, financing water resources management and development at the basin level is a major challenge, evidenced by the financial hurdles experienced by catchment-based institutions such as the WRA and WRUAs. This implies that an innovative resource mobilization strategy which recognize the role of the county governments, water sector institutions and the private sector in catchment protection and conservation is urgently required. Such an arrangement could release predictable and reliable flows of finance, which are critical to enabling catchment interventions that are planned, sustainable and transformative.

WATER AND SANITATION STRATEGIC PLAN 2018–2022

This is a critically important Plan formulated by WASREB.[124] It seeks to provide a regulatory environment that facilitates efficiency, effectiveness and equity in the provision of water services in line with the human right to water and sanitation. The Plan identifies a number of challenges to water service provision such as: *ad hoc* outreach to stakeholders, weak engagement with county governments, lack of coordinated and harmonized work plans, and inadequate funding to the regulator. To solve some of these challenges, the Strategic Plan proposes the need for partnerships with development partners and private sector to provide funding and technical expertise. It further points out that goodwill accrued from such partnerships would enable WASREB to execute a number of proposed programs successfully and attract more financing to the sector.

COUNTY INTEGRATED DEVELOPMENT PLANS

County Integrated Development Plans (CIDPs) are five-year plans that set out each county's financial and economic priorities. The plan touches on all sectors devolved to county governments, and provides a roadmap for development. Catchment protection and water and sanitation services are devolved functions and as such feature in all CIDPs. A review of the CIDPs showed that planned activities related to water resources mainly revolve around rehabilitation of old pipe networks, extension of distribution network, development of new water sources including boreholes and small dams/pans, extension of sewer networks and expansion of sewer treatment plants. The key development aspects of the CIDP for Mombasa,

[122] Ibid, p. 143
[123] Ibid, p.156
[124] https://wasreb.go.ke/downloads/WASREB%20Strategic%20Plan%202018-2022%20final.pdf (accessed 11 April 2021).

Kwale, Taita Taveta and Kilifi counties which are relevant to water resources management are briefly described in the context of water and sanitation.

Mombasa CIDP (2018-2022)

Mombasa has underdeveloped water supply systems.[125] Programmes to improve this are sanitation blocks and sludge treatment plants, sewer systems and storm water systems, waste water treatment plants, water supply pipelines, water bowsers, water storage, boreholes, and policy review.

Kilifi CIDP (2018-2022)

Programmes include increased access to water supply, diversification of water sources, catchment rehabilitation and improved sanitation services. Flagship projects include Rare, Sabaki and Gwaseni/Mbubi dams.[126]

Kwale CIDP (2018-2022)

These sectors include Agriculture and Rural Development and Water Services and Infrastructure.[127] The County has deliberately established piped water programs and is keen on delivering on water services.

Taita Taveta CIDP (2018 – 2022)

The County has the biggest water supply scheme in the coastal region. This is the Mzima Water Project, which supplies water to Voi town and its environs through a number of major projects including Voi water supply, Mbololo water supply, Irima, Kimwa and Kaloleni water projects, Miasenyi water project, Manyani water supply, and Maungu-Bughuta water project.

This scheme is also among the major suppliers of water in the coastal city of Mombasa. The source of the water is Mzima springs, situated in the Tsavo West National Park. Other major water schemes are found in Taveta and Wundanyi areas. In Taveta, there are four schemes. These are Taveta Lumi water supply, Challa Water Project, Chumvini water project, and Kitobo water project.

INSTITUTIONAL LANDSCAPE

The institutional frameworks for the sound management of catchment areas and water resources management and development is three tiered – the first tier bearing the responsibility of policy formulation, the second bearing the responsibility for supervision and coordination of policy implementation, and the third having responsibility for implementation, monitoring and enforcement.

Governance of water resources management and services, land, forests is thus scattered across many policy domains and legislations, with diverse institutions charged with natural resources management. The Water Act (2016), for example, has established many institutions: the Water Resources Management Authority (WRMA) is replaced with the Water Resources Authority (WRA) to protect, conserve, control and regulate use of water resources.[128] Similarly, the Catchment Area Advisory Committees (CAAC) are replaced with Basin Water

[125] https://kecosce.org/county-government-of-mombasa-second-county-integrated-development-plan-2018-2022/(accessed 11 April 2021)
[126] https://www.kilifi.go.ke/library.php?com=5&com2=129(accessed 11 April 2021)
[127] http://kwalecountyassembly.co.ke/documents/county-integrated-development-plan/(accessed 11 April 2021)
[128] Section 12 of the Water Act (2016).

Resources Committees (BWRCs) to play an advisory role to the WRA and county governments in water resources management.[129] Other changes to the to the institutional framework include the replacement of the WSBs with Waterworks Development Agencies (WWDAs), Local Authority water service providers (WSPs) with county government WSPs, National Water Corporation with the National Water Harvesting and Storage Authority, Water Service Trust Fund with Water Sector Trust Fund, and Water Appeal Board with Water Tribunal. The institutional structure of the water sector is presented in Figure 9-1. The institutions are discussed below.

National level	Ministry of Water and Sanitation & Irrigation		Policy Making
	Water resources	Water services	
	Water Resources Authority (WRA)	Water Services Regulatory Authority (WASREB)	Regulation
Regional level	Basin Water Resources Committees (BWRCs)	Water Works Development Agencies (WWDAs)	Service provision
Local level	Water Resource Users Associations (WRUAs)	Water Service Providers (WSPs)	
	Consumers		Consumption, use

	National Water Harvesting & Storage Authority	Water Tribunal	Water Services Trust Fund	
National level	Ministry of Water and Sanitation & Irrigation			Policy Making
	Water resources		Water services	
	Water Resources Authority (WRA)		Water Services Regulatory Authority (WASREB)	Regulation
Regional level	Basin Water Resources Committees (BWRCs)		Water Works Development Agencies (WWDAs)	Service provision
Local level	Water Resource Users Associations (WRUAs)		Water Service Providers (WSPs)	
	Consumers			Consumption, use

Figure 9-1 Representation of institutional framework for the Water Sector under the Water Act (2016) (Adopted from National Water Act, 2016)

MINISTRY OF WATER, SANITATION AND IRRIGATION

The Ministry of Water, Sanitation and Irrigation is the institution responsible for the water sector in Kenya including development of legislation, sector coordination and guidance, monitoring and evaluation, sector investments, planning and resource mobilization. The vision of the Ministry is to ensure water resources availability and accessibility to all. Similarly, its mission is to contribute to national development by promoting and supporting integrated water resource management to enhance water availability and accessibility. The objectives of the Ministry are well aligned with its mission, and include: (i) accelerating the implementation

[129] Section 27 of the Water Act (2016).

of water sector reforms; (ii) improving the sustainable management of water resources; (iii) improving the provision of water and sewerage services; (iv) improving utilization of land through irrigation and land reclamation; (v) strengthening institutions in the Ministry and the water sector; (vi) mobilizing resources and promoting efficiency in their utilization; and (vii) improving the management and access to water resources information.

THE WATER RESOURCES AUTHORITY (WRA)

Water Resources Authority (WRA) was established under Section 11 of the Water Act (2016) as an agent of the national government responsible for the implementation of policies and strategies relating to management of water resources. Specifically, the Water Act (2016) provides for the WRA to protect, conserve, control and regulate use of water resources. Further, the role of WRA has been extended to include the classification of water resources for purposes of determining water resource quality objectives.[130] WRA is also responsible for ensuring the presence of a national monitoring and geo-referenced information system for water resources.[131] The Water Act (2016) provides that information on water resources shall be accessible to the public at a prescribed fee.[132] This is in accordance with Article 35 of the Constitution, which provides for the right of access by the public to information held by the state.

In discharging its mandate, WRA works in close collaboration with other regulatory bodies, such as Kenya Wildlife Services (KWS), Kenya Forest Service (KFS), National Environment Management Authority (NEMA), Kenya Water Towers Agency (KWTA), and county governments.

The WRA has adopted a decentralized and participatory structure, and operates six Regional Offices and 26 subregional offices across the country. The Water Act (2016) provides for a Management Board and sets out the composition of its members.[133] The composition of the Board members reflects the recognition of the need for coordination between related sectors such as finance, environment and land.

In the Mwache Dam catchment, the WRA is collaborating with various stakeholders in catchment management. For example, WRA is working closely with CDA to mobilise communities in the catchment area to form WRUAs. Under the Mwache Dam project (KWSCRP2), 24 WRUAs have been registered in Mwache Dam catchment, and 13 supported to develop sub-catchment management plans (SCMPs).[134]Moreover, The WRA has marked and riparian reserves to protect them from agricultural encroachment.[135] This will allow the regeneration of indigenous vegetation in the riparian reserves, reduce soil erosion and sediment loads to the Mwache Dam.

[130] Section 24 of the Water Act (2016).

[131] Section 21(1) of the Water Act (2016).

[132] Section 21(3) of the Water Act (2016).

[133] Section 14(1) of the Water Act (2016).

[134] Interviews with Ahmed Mbarak, Assistant Technical Coordinator – Surface Water, Coastal Athi Sub-Region, Water Resources Authority.

[135] Interview with Mwanasiti Bendera, Manager of Planning, Development and Research Manager, Coast Development Authority, 7th July 2021

THE WATER SERVICES REGULATORY BOARD (WASREB)

The Water Services Regulatory Board (WASREB) is a regulatory state corporation established by the Water Act (2016). It sets, monitors and reviews rules and regulations to ensure water services provision is affordable, efficient, effective and equitable. Among the powers and functions of WASREB under the Act include: (i) determining and prescribing national standards for the provision of water services and asset development for water services providers; (ii) evaluating and recommending water and sewerage tariffs to the county water services providers and approving the imposition of such tariffs in line with consumer protection standards; (iii) setting licence conditions and accrediting water services providers; (iv) monitoring compliance with standards including the design, construction, operation and maintenance of facilities for the provision of water services by the waterworks development; (v) maintaining a national database and information system on water services; and developing guidelines on the establishment of consumer groups and facilitating their establishment.[136]

The Water Act (2016) gives county governments the mandate for water service provision and development of county water works. Accordingly, the county governments are required to set up WSPs which should be commercially managed and licensed by WASREB. The license sets out conditions and targets of performance to be observed by WSPs to ensure quality in service provision. Among conditions for commercially viable WSPs is a duty to conserve water resources and report to the WASREB on water source protection and measures.[137] When setting the tariffs, WASREB allows WSPs a component to cover activities undertaken to ensure conservation of water resources. This is based on the realization that water supply and treatment costs are affected by upstream activities.[138] This license condition for source water protection provides the basis for establishment of a water fund.

NATIONAL WATER HARVESTING AND STORAGE AUTHORITY

The National Water Harvesting and Storage Authority (NWHSA) is mandated to "develop and manage national public water works for water resources management and flood control; and to develop and implement water harvesting policy and strategy.[139] The establishment of the National Water Harvesting and Storage Authority more closely aligns the constitutional provisions on the role of the national government with the institutional framework established by the Water Act (2016). One of these roles is the national government's obligation to secure sufficient residual water, a task assigned to this Authority. It is hoped that the Authority will address problems of insufficient water harvesting. Currently, approximately 43% of the total water generated in the country is either lost or unaccounted for.[140] Further, the National Water Harvesting and Storage Authority is expected to be instrumental in ensuring that national government meets its obligation to secure the human right to water of all Kenyans. Currently, Kenya's per capita consumption stands at approximately 43 liters per person per day.[141]

---

136 Section 72(1) of the Water Act (2016)

137 Republic of Kenya, Licence conditions for provision of water services: medium and very large WSPs, WASREB

138 Interview with Peter Njaggah, Acting Chief Executive Officer, WASREB, July 12th 2021

139 Section 32 of the Water Act (2016)

140 Water Services Regulatory Board (2016)

141 Ibid.

THE WATER TRIBUNAL

Under the Water Act (2016), the Water Appeal Board has been replaced by the Water Tribunal.[142] Appeals from decisions of the WRA in relation to applications for permits go to the Water Tribunal.[143] The Chairperson of the Tribunal and other staff are appointed by the Judicial Service Commission and not by the President or the Minister. The jurisdiction of the Water Tribunal is wider than that of the Water Appeals Board. Any person directly affected by the decision or order of the Cabinet Secretary, WRA, WASREB or any person acting under their authority, can appeal to the Tribunal despite not having a right or proprietary interest.[144]

WATER SECTOR TRUST FUND

The Water Sector Trust Fund was established under the Water Act (2016) to replace the Water Services Trust Fund. The fund has been transformed from a financing mechanism to a financing institution. Further, the Water Act (2016) includes provisions for funding of counties through conditional and unconditional grants, to assist in financing their development and management of water services in marginalized or underserved areas. Such financing extends beyond direct service provision activities to include community-level initiatives for sustainable management of water resources and research activities in the areas of water resource management.[145]

The Water Sector Trust Fund is critical for successful implementation of devolved water governance. The Act provides for the various sources of money for the Fund, which include "monies appropriated by Parliament national budget, provided to the Fund from the Equalization Fund, provided to the Fund by a county government, and received by the Fund from donations, and grants".[146] The Water Sector Trust Fund enlarges the scope for collaboration with county governments over water services; WRA, WRUAs and county governments over catchment protection and management; and private investors over resource mobilization for onward lending to credit worthy utilities.

THE BASIN WATER RESOURCES COMMITTEES

The Water Act (2016) uses the term 'basin area' to refer to a defined area from which rainwater flows into a watercourse.[147] The term catchment area under this Act means an area that is part of a basin.[148] The Basin Water Resources Committees (BWRCs) are responsible for managing water resources within their respective basin areas. The composition of these Committees and their mode of operation are provided for in detail under the Act.

The Water Act (2016) caps the membership to the BWRC at seven.[149] This includes a representative of the ministry for water resources, farmers or pastoralists, NGOs engaged in water resources management programs, business community operating within the basin area, and county government whose territory falls within the basin.[150] In this way, the BWRCs is

[142] Section 119 of the Water Act (2016).
[143] Ibid.
[144] Section 121 of the Water Act (2016).
[145] Section 114 of the Water Act (2016).
[146] Section 117 of the Water Act (2016)
[147] Section 24 of the Water Act (2016).
[148] Section 2(1) of the Water Act (2016).
[149] Section 26(1)(a) of the Water Act (2016).
[150] Section 26 of the Water Act (2016).

giving effect to participatory decision-making processes on water resources management. The county representative in the BWRC is nominated by the WRA and approved by respective county assembly. For this reason, the Water Act (2016) provides for county governments to play a key role in water resources management.

The BWRCs are mandated to formulate basin area water resources management strategies in consultation with the WRA and county governments whose territories lie within the basin.[151] These strategies provide a critical guide for water resources management in the basin, and are required to, among others, outline specific measures for "sustainable management of water resources, incorporate water resource allocation plan, provide systems for collaborative water governance, develop financing plan, and facilitate the formation of WRUAs".[152]

The Water Act (2016) places a mandate on counties to protect and conserve water catchment areas. However, there is a lack of legal clarity on the institutional mechanisms through which counties can manage water resources that fall within their territories and how they will relate with the BWRCs and community-based organizations such as WRUAs to support the WRA in basin-level water resources management activities. County governments want to operate within their administrative boundaries.[153] It is anticipated that the BWRCs will provide a platform to ensure better coordination between the WRA and the county governments. While the tenure of the members of BWRCs is secure under the Water Act (2016), they are still appointed by the WRA in consultation with the Cabinet Secretary in-charge of water resources. This appears to undermine its independence in coordinating the implementation of catchment management interventions. Another weakness of the Water Act (2016) is that it gives counties no direct role in nominating BWRC members. This can undermine the opportunity to promote coordinated approaches to water resources management. However, this risk mitigated if the Minister makes appointment in consultations with county governments.

WATER RESOURCES USERS ASSOCIATIONS

Water Resources Users Associations (WRUAs) are established at the sub-basin level to promote cooperative governance and address water-related conflicts.[154] While WRUAs are community-based voluntary organisations, they are critical for sustainable water resource allocation and use. According to the Water Act (2016), BWRCs and WRA may contract WRUAs as agents to perform certain duties in water resource management.[155] This points to a more formal and expanded mandate of WRUAs in the management of water resources at the sub basin level. Similarly, it shows that WRUAs have a legal mandate in sub-basin water governance and can take up formal governance responsibilities, such as implementation of water resource management strategies. Although the Water Act (2016) has expanded the mandate of WRUAs, it has failed to incorporate appropriate measures for financial sustainability. The Water Act (2016) makes a weak attempt to address financial sustainability of WRUAs through a provision which allows an agreement with the WRA to make available

[151] Section 28 of the Water Act (2016)
[152] Ibid
[153] Interview with Chrispine Juma, Director of Water Resources, Ministry of Water & Sanitation and Irrigation, June 25th 2021.
[154] Section 29 of the Water Act (2016)
[155] Section 29(4) of the Water Act (2016).

a portion of water use charges to support regulatory functions undertaken on WRA's behalf.[156]

Moreover, WRUAs' ability to promote catchment conservation and ensure equitable water allocation is challenged by limited technical capacity. This not surprising because WRUAs are run by volunteers who can easily lose commitment. WRUAs are built on voluntary membership with a large segment of members drawn from small-scale farmers. Corporate organizations within the sub-catchment are hardly represented in WRUAs.[157]

Despite these challenges, many government institutions are working with WRUAs to support the implementation of catchment management and water source protection measures.[158] In the Mwache Dam catchment area, 24 WRUAs have been registered, and 13 have been supported by the CDA and WRA to develop sub-catchment management plans (SCMPs) to promote water conservation and catchment restoration.[159] The SCMPs took note of the connection between livelihoods and ecosystems in the management of water resources. Specifically, SCMPs seeks to ensure equitable water allocation, reduce water pollution, promote sustainable land management practices, improve agricultural productivity and protect riparian reserves from human encroachment.

The Mwache Dam catchment has been severely degraded by population growth, poor farming methods, deforestation, sand harvesting and quarrying and charcoal burning. Nearly all mature trees in the lower reaches of the catchment have been cut down for charcoal production and regenerating shrubs for firewood.[160] As a result, CDA and WRA is collaborating with local communities and other institutions to rehabilitate and restore the catchment. Specifically, WRUAs and CDA with WRUAs are implementing soil conservation practices, such as terracing and reforestation projects.[161]

WATER WORKS DEVELOPMENT AGENCIES

The Water Works Development Agencies (WWDAs) are mandated to undertake the development, maintenance, management and operation of national public water works in their jurisdiction.[162]Similarly, it is tasked with providing reserve capacity, technical services and capacity building to county governments and WSPs in their respective areas.[163]

The Water Act (2016) provides for the handing over of national public works' assets to the county government, the joint committee or authority of the county governments within whose area the water works fall, or to the relevant WSP for purposes of provision of water services.[164] However, the transfer of the assets is subject to the payment of any outstanding liabilities. Additionally, the Water Act (2016) allows WWDAs to take over the functions of

[156] Section 42(3) of the Water Act (2016)
[157] Interview with Chrispine Juma, Director of Water Resources, Ministry of Water & Sanitation and Irrigation, June 25th 2021.
[158] Interview with Kennedy Olwasi, Assistant Director of Programmes, Projects and Strategic Initiatives, Ministry Environment and Forestry, June 23rd 2021
[159] Interview with Mwanasiti Bendera, Manager of Planning, Development and Research Manager, Coast Development Authority, 7th July 2021
[160] Ibid
[161] Ibid
[162] Section 68 of the Water Act (2016)
[163] Section 68 of the Water Act (2016).
[164] Section 69 of the Water Act (2016).

WSPs in case of a default in the repayment of any outstanding loans arising from the development and maintenance of the water works, or a breakdown in the provision of water services.[165] However, WWDAs will need a license from WASREB to operate as WSP. Currently, the Water Act (2016) does not provide for the regulation of WWDAs by WASREB. The Water Act (2016) may need to be amended for WWDAs to be a fallback plan should water service provision by utilities fail.[166]

KENYA WATER TOWERS AGENCY (KWTA)

Kenya Water Towers Agency (KWTA) is a State Corporation mandated to coordinate and oversee the protection, rehabilitation, conservation and sustainable management of water towers in Kenya.[167] The Agency established under Kenya Gazette Supplement No. 27, Legal Notice No. 27 of 20th April 2012, of the State Corporation Acts (Cap 446), falls under the Ministry of Environment and Forestry.

The functions of the agency include: (i) Co-ordinating and overseeing the protection, rehabilitation, conservation, and sustainable management of water towers, including the recovery and restoration of forest lands, wetlands and biodiversity hot spots; (ii) promoting the implementation of sustainable livelihood programmes in the water towers in accordance with natural resource conservation; (iii) mobilizing resources from the Government, development partners and other stakeholders as well as through payment for environmental services, including carbon reservoirs and sequestration; (iv) identifying water towers and watershed for protection, in consultation with the relevant stakeholders; and (v) assessing and monitoring rehabilitation, conservation and management activities in the water towers.

The current establishment of KWTA via legal gazette is inferior to institutions established through Acts of Parliament (KWS, KFS, WRA, NEMA etc.) which challenges its ability to coordinate such institutions. The Kenya Water Towers Bill 2019, therefore seeks to strengthen the legal mandate of the Agency by making provisions for the establishment of the Kenya Water Towers Authority. The substantive provisions of the Bill provide for coordination and conservation of water towers. Specifically, the Bill, under section 46, allows the Cabinet Secretary, recommendation of the KWTA to make regulations for the payment of ecosystem services for purpose of sustainable management of the water towers.

NATIONAL ENVIRONMENT MANAGEMENT AUTHORITY (NEMA)

NEMA was founded and mandated under EMCA to exercise general supervision and coordination over all matters relating to the environment and to be the principal instrument of the government in the implementation of all policies relating to the environment.

KENYA FOREST SERVICE (KFS)

KFS was established by the Forest Conservation and Management Act, 2016 to develop and sustainably manage forest resources for the socio-economic development of Kenya. The

[165] Section 69(3) of the Water Act (2016).
[166] Interviews with Peter Njaggah, Acting Chief Executive Officer, WASREB, July 12th 2021
[167] https://watertowers.go.ke/ (accessed 11 April 2021).

overall mandate of KFS is to conserve, develop and sustainably manage gazetted forestry resources including in the Water Towers.

KENYA WILDLIFE SERVICE (KWS)

Established under the Wildlife (Conservation and Management) Act (2013), KWS is mandated to formulate and implement policies for the conservation, management and utilization of wildlife resources, national parks and reserves. Though KWS does not directly manage water resources, it is charged with the responsibility to manage the water environment and ecosystems falling within their jurisdiction. KWS works in close collaboration with WRA, NEMA, KFS, county governments and other organized groups including private sector and local communities to monitor and enforce actions against degradation and loss of wildlife habitats.

KENYA FORESTRY RESEARCH INSTITUTE (KEFRI)

KEFRI was established under the Science and Technology Act (Chapter 250) to carry out research in forestry and allied natural resources. Its mandate is to conduct research in forestry, to disseminate research findings, and to co-operate with other research bodies carrying out similar research within and outside Kenya.

NATIONAL IRRIGATION DEVELOPMENT AUTHORITY

The National Irrigation Authority was established by the Irrigation Act No. 14 of 2019 as a successor institution of the National Irrigation Board.[168] Its objective is to provide for the development, management and regulation of irrigation, to support sustainable food security and socioeconomic development in Kenya.

Irrigation in Kenya is well anchored in Vision 2030, the Third Medium Term Plan (MTP III) 2018 2022, Big Four Agenda 2018-2022 and further cascaded in the Authority's Strategic Plan 2019-2023. The Irrigation Act is further intended to support sustainable food production by clearly outlining the roles of national and county governments in facilitating irrigation activities in Kenya. NIA is mandated to formulate and be responsible in conjunction with the WRA for the execution of policy in relation to national irrigation schemes. Additionally, it is tasked with raising of funds for the development of national irrigation schemes.

NATIONAL GOVERNMENT MINISTRIES

The ministries responsible for agriculture, water, land, fisheries, forestry and wildlife bear some level of responsibility for diverse aspects of water catchment governance, with their primary role mainly being policy formulation. Appreciating the fact that there are issues that transcend the mandate of any one ministry, inter-ministerial collaboration is required. Other coordination units include the Kenya Water Towers Agency and Agricultural Sector Coordination Unit which bring various ministries together for coordinated development and implementation of policies and strategies.

[168] https://irrigation.go.ke/our-history (accessed 11 April 2021).

COAST WATER WORKS DEVELOPMENT AGENCY (CWWDA)

In accordance with the Constitution, the Water Act (2016) transfers the responsibility of water service provision to county governments.[169] County governments are responsible for establishing WSPs (public limited companies under the Companies Act 2015), which shall be responsible for providing water services within the specified area and for developing county assets necessary for water service provision.[170]

The Water Act (2016) attempts to mitigate the risk of political capture of WSPs by setting out clear conditions for WSPs when applying for licenses. Members of the Board of a WSP cannot at the time of nomination for appointment be serving as elected members of a county government; hold office in a political party; or be serving members of Parliament.[171] The Act further requires that the application for a license as a WSP, made to WASREB, must be publicized and subjected to the input of stakeholders including the county government. The Act includes clear provisions on the requirements for an application and grounds for revocation or suspension of a license. An application for a license must include, among other things, evidence of a business plan, financial capability and plans for infrastructural development as a safeguard against financial and technical challenges.

As noted above, the Act seems to have adopted a prudent and slow approach to devolving water service provision to county governments. The experience of the health sector in which a rapid devolution of health service provision to county governments resulted in a crisis supports the wisdom of taking a staggered and prudent approach. The rushed devolution in the health sector was characterized by duplication of roles by national and county governments, inadequate support and financing of systems and processes at county government levels, and delays in accessing resources resulting in a failure by county governments to manage their health units.[172]

Given the critical need for sustainable water management in Kenya, there may be some wisdom in retaining some control of water services' management and provision at the national level to avoid a similar scenario as that faced in the health sector. Further, given the intra-county geographical extension of water resources, the management of water resources and even water service provision in some cases ought to remain within the mandate of the national government to ensure the sustainability of these water resources. As the experience of other countries demonstrates, the challenges faced in achieving sustainable management of basin areas that cut across states and territories has led to an increased move towards greater control by the federal government.[173]

For purposes of this study, it is important to highlight that the Coast Water Works Development Agency (CWWDA) covers Mombasa, Kwale, Kilifi and Taita Taveta counties. The WWDAs have on-going and proposed projects that vary from rehabilitation of water supply schemes, extension of service lines, construction of storage tanks and drilling and equipping of boreholes in all the counties, to major dam and water resource projects.

---

[169] Section 77 of the Water Act (2016).
[170] Ibid.
[171] Section 80 of the Water Act (2016).
[172] Kimathi, L (2017) "Challenges of the devolved health sector in Kenya: teething problems or systemic contradictions?" XLII (1) Africa Development 55.
[173] McKay J & S Marsden (2009) "Australia: the problem of sustainability in water" in JW Dellapenna & J Gupta (eds) The Evolution of the Law and Politics of Water.

KEY POLICY, LEGAL AND INSTITUTIONAL GAPS

Effective policies, laws and institutions are critically important in creating enabling environment for watershed management. However, Kenya does not have dedicated law or legal provisions on water funds. This has in part contributed to a deficit in conservation finance. The environment sector plays a key role in Kenya's economy, securing and sustaining the environment and natural capital of the country. The sector has a great potential in contributing to the attainment of the targeted annual GDP growth rate of 10 percent as envisioned in Vision 2030. Despite its contribution to the economy and potential for further growth, budgetary allocation to the sector decreased substantially from Kshs.84.710 billion in 2016/17 to Kshs.72.896 billion in 2018/19.[174] Currently, there is overreliance on external funding for conservation Yet, innovative pathways for resource mobilization are available from private, domestic and international sources. While a variety of water tariffs and levies are charged to support conservation and management activities, the resources have not been properly allocated to preserve and conserve surface and groundwater sources. It is not clear whether these funds are adequately ring-fenced and applied for catchment conservation and management purposes. The water sector continues to face many resource mobilization challenges, including weak operational and governance performance by utilities, which undermine solvency and commercial viability; inefficiency in revenue collection; and high levels of non-revenue water - all resulting in low cost recovery.

Water is in high demand not just for agriculture but for other social and economic uses. Schemes that offer payment for environmental services such as Water Funds are often proposed as a market incentive to secure water supply. However, payment for environmental services schemes have proved difficult to put into practice in Kenya due to weak governance structures. Finding the right incentives, institutional mechanisms and monitoring legal regimes while incorporating various stakeholders' concerns have proven complicated.[175] Overall, Kenya is characterized by disjointed infrastructural investments, a lack of synergy, and poor targeting to address different needs and inefficiencies. While the country's conservation policies are impressive, efforts to coordinate national and county actions are hampered by sectoral budgeting processes. Each sector such as water, lands, forestry and agriculture at both levels of government have own budget to meet sectoral mandates. Despite the availability of coordinating units, such as inter-ministerial collaborations and Kenya Water Towers Agency, relevant government agencies are still stuck in their silos.[176]

RECOMMENDATIONS

There are both design and implementation gaps and challenges in the various laws, policies and institutions relating to water resources management and catchment conservation which would hamper setting up MWF. They have been discussed and the study offers some viable solutions which would enable the Fund to thrive in its operations.

[174] Republic of Kenya. (2019). Environment Protection, Water and Natural Resources Sector Report for the Medium Term Framework Period 2020/21-2022/23: Draft Report

[175] https://wle.cgiar.org/news/breaking-new-ground-water-funds(accessed 11 April 2021).

[176] Interview with Kennedy Olwasi, Assistant Director of Programmes, Projects and Strategic Initiatives, Ministry of Environment and Forestry, June 23rd 2021.

POLICY, LEGAL AND INSTITUTIONAL GAPS AND POSSIBLE SOLUTIONS

A number of gaps that have been identified are discussed below.

No Specific Law on water funds

The water fund concept is not explicitly rooted in relevant policies and legislations, with no dedicated legal provisions around water funds.[177] However, the Water Tower Bill (2019) has proposed the establishment of a PES scheme to promote water tower protection and rehabilitation. Section 46 of the Bill mandates the Cabinet Secretary responsible for catchment management, on recommendation of the proposed KWTA, to make regulations for or with respect to the payment for ecosystem services. Noting that the water fund can finance conservation through PES, this will provide the basis to expedite the enactment of the Bill. Despite the absence of specific law or dedicated legal provisions on a water fund, existing policies and legislations on water, land and forestry provide for public-private partnerships and community participation in natural resources management. Similarly, the Public-Private Partnerships Act (2013) lays emphasis on the formation of business-oriented partnerships to provide incentives for conservation through the creation of livelihood benefits. Further, natural resources policies provide for public and private sector engagement with local communities to support sustainable land and water management initiatives. This implies that a water fund can be used as a financing mechanism for watershed.

Currently there are several laws addressing watershed protection and conservation. From the Constitution to the statutory provisions - Water act, EMCA, Forest Management and Conservation Act, Wildlife Management and Conservation Act, Land Act, National Land Commission Act, Community Land Act – fragmented laws have created gaps and confusion in the catchment protection. The Environmental Management and Coordination Act (Amendment) Act, as a framework law is deemed to be overarching. This implies that those sectoral legislations would be aligned to the framework law. However, this is not the case in practice. In the current scenario where the Acts dealing with the environment came into force at different times without reference to each other, they might be deemed to be operating independently which compromises the integrity of the environment where an ecosystems-based approach would be desirable.

Despite these coordination challenges, existing policy, legal and institutional frameworks on natural resources management lay sound foundation for participatory decision-making in natural resources management. The water fund can capitalize on these existing frameworks to engage and partner with governments, private sector and communities in watershed conservation and management.

Law is very grey on inter-county linkages

The Water Act (2016) is grey on inter-county linkages. The Mombasa Water Fund would require cross-county collaboration because the Mwache Dam catchment traverses four Counties – Mombasa, Kwale, Kilifi and Taita Taveta. This poses a challenge to the Mombasa Water fund. However, existing institutions, such the Council of Governors (CoG) and Jumuiya ya Pwani – a regional economic block for Kenya's coastal counties – can serve as platforms for cross-county collaboration and joint action towards conservation of the Mwache Dam catchment. The Council of Governors, through its relevant technical committees on

[177] Interview with Kennedy Olwasi, Assistant Director of Programmes, Projects and Strategic Initiatives, Ministry of Environment and Forestry, June 23rd 2021.

environment, water and land, can enhance inter-county cooperation on issues of common interests. The water fund can leverage on Jumuiya ya Pwani and CoG to mobilize resources for conservation and management of the Mwache Dam catchment. Additionally, the Water Fund will also prompt county governments to enact enabling inter-county legislation to address issues around Mwache Dam catchment.

Limited coordination

Water resources are dependent on healthy ecosystems, particularly in high rainfall, high altitude areas (known in Kenya as water towers). However, the different agencies of government such as WRA, KFS, KWS, and KWTA operate in the same space without a framework to guide how they can coordinate their activities.[178] These institutions have their own strategies and budgets and tend to focus attention on meeting specific institutional mandates. Existing regulatory instruments also do not provide frameworks to guide how national government agencies and county governments can coordinate their programs and activities, and engage with community-based conservation groups, such as WRUAs. Moreover, there is no policy or legal provision for linking the programs and activities of WRUAs and other sector agencies with those of county governments. The absence of a coherent framework to guide how these institutions can coordinate their affairs has thus created institutional conflicts. As a result, their strategies do not reinforce each other nor create synergies for sustainable practices in catchment management. Coordination between county governments sharing a water catchment is also often lacking.

The proposed Mombasa Water Fund will bring together relevant public agencies and county governments to pool resources and responsibility for the conservation of Mwache Dam catchment. The water fund will potentially enhance inter-sectoral collaboration and create a framework upon which actors can coordinate catchment management interventions. A multi-stakeholder water fund governance model would bring together diverse stakeholders in the management of the proposed water fund.

Revenue collection and resource mobilisation challenges

Financing watershed conservation and restoration remains a serious challenge for governments. Despite efforts to close conservation funding gap through mobilization of financial resources from private markets and development partners, the problem persists. Water fund is viewed as a promising mechanism to close conservation financing gap in watershed management.[179] In the pursuit of alternative sources of financing, MWF is expected to attract funding from diverse sources, including water utilities. Diverse sources of finance are critical for financial sustainability, and to ensure the mobilization of sufficient resources and protect against overreliance on single source of funding.

GOVERNANCE ISSUES

Water resources management decisions in Kenya are often influenced by political agendas, which are hardly aligned with evidenced-based planning. This creates unrealistic expectations and often leads to frustration. Furthermore, there is a perception that institutions responsible for natural resources management are more focused on achieving conservation policy targets

[178] Interview with Chrispine Juma, Director of Water Resources, Ministry of Water & Sanitation and Irrigation, June 25th 2021.

[179] Nelly Aroka. Rainwater Harvesting in Rural Kenya Reliability in a Variable and Changing Climate. Available https://www.diva-portal.org/smash/get/diva2:354235/FULLTEXT02.pdf (Accessed 14 June 2021)

through application of command-and-control measures. This in creates animosity between local communities and enforcement agencies, which can negatively impact conservation on the ground. Furthermore, ensuring that water fund governance arrangements reflect local interests is a challenge. Failure to incorporate local interests in the water fund governance can affect the implementation of the MWF .

Limited partnerships

Partnerships are very important in water catchment projects. There are a few partnerships in place, majority being nationwide partnerships with key strategic partners whose focus is nationwide, such as those on infrastructure development The proposed MWF will create localised partnerships to coordinate and provide long-term resources for catchment protection. A multi-stakeholder governance model will bring together various stakeholders from governments, private sector, CSOs and communities.

Trans-county conflict

The Constitution devolved water services provision to county governments. However, practical arrangements for trans-county water transfers were not clarified. This has led to conflicts, particularly between the counties within the Athi Basin often due to trans-county water supply.[180] A false idea has been created that water belongs to counties if the source is within their territory. Conflict is heightened during a drought when water availability is at a minimum.

There has been a lot of tension between Murang'a and Nairobi counties during the construction of the Northern Water Collector Tunnel. Recent tension arose when AWWDA neglected to uphold the agreement, which requires them to supply water to local communities in Murang'a County before commencing construction of the tunnel to Nairobi. In the middle course of the Athi River Basin, water resource conflicts have been reported between Kajiado, Machakos and Makueni counties. In 2017, the Governor of Kajiado instructed Nolturesh-Loitokitok Water and Sanitation Company to disconnect the water supply to Machakos and Makueni counties to ensure uninterrupted supply to Oloitokitok and satellite towns with Kajiado county.

Similarly, there has simmering tension in Kwale County due to water scarcity in the area, while neighbouring Mombasa is supplied with water from sources in Kwale County. Similarly, there is a conflict between Mombasa, Kilifi and Taita Taveta counties over shared water resources. Currently, the CWWDA manages the Baricho-Sabaki Well field, Mzima Pipeline, Marere Pipeline and Tiwi Boreholes, which supply Mombasa.

However, the planned Joint Water and Sanitation Authority for coastal counties of Mombasa, Kwale and Kilifi is expected to ensure equitable distribution of water and reduce trans-county conflicts over water supply. The joint authority will oversee the provision of water services at the Coast through a Bulk Water System. The Mwache Dam will be part of a larger bulk water system to be handed over to the joint authority. The establishment of a Joint Water and Sanitation Company for Coastal counties provides a better platform for to ground the proposed MWF.

[180] Ibid.

10 STAKEHOLDERS IN A "MOMBASA WATER FUND"

CONCEPTUAL FRAMEWORK AND APPROACH

Our initial identification of stakeholders drew on the stakeholder mapping exercise undertaken by Rural Focus Ltd (2020) as part of the pre-feasibility study. This was supplemented by our review of the institutional landscape regarding the use and management of water resources in the Coast region and Kenya as a whole. The initial desktop identification and mapping of stakeholders was supplemented by engagement with a number of key stakeholders through virtual and in-person meetings in Mombasa and Nairobi. This gave us a clearer understanding of the interests and relevance of various stakeholders in relation to the MWF, allowing us to revise and refine our understanding of the institutional landscape and the roles different stakeholders might play in supporting the MWF. It also provided us with valuable insight into potential barriers and stakeholder concerns that warrant consideration in the design of the fund. Additionally, our engagements also provided an opportunity for the stakeholders themselves to gain a better understanding of the proposed fund and address any questions and concerns to the team of consultants.

Following our desktop review and stakeholder engagement process, we classified stakeholders in terms of their estimated level of interest in the MWF and their level of influence over its success. This enabled us to place potential stakeholders in one of the four quadrants shown in Figure , to help determine the appropriate level of engagement relative to their influence and interest in the fund. The highest priority stakeholders are those placed in the "work with" category, as they are judged to have both a high interest in the MWF and a high level of influence over its successful implementation. The list of stakeholders considered contains a variety of actors, including key government regulatory and management bodies from national to local level, financing and donor organisations who might have an interest in supporting the MWF as well as private companies and business associations whose operations could be heavily impacted by water availability.

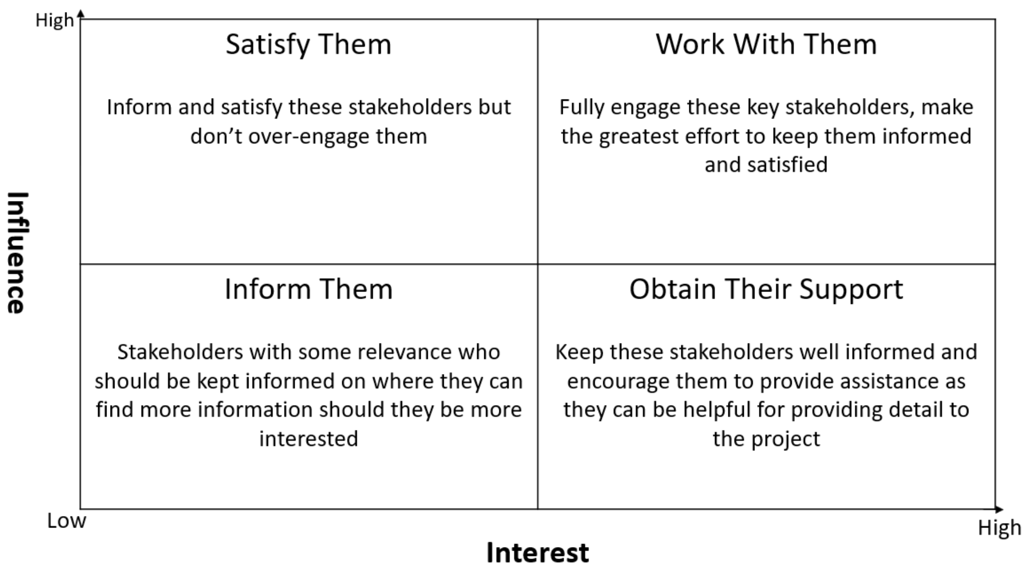


Figure 10-1. Conceptual framework for the stakeholder analysis

OUTCOME OF STAKEHOLDER ANALYSIS

The full analysis and categorization of relevant stakeholders to the MWF is summarized in Table 10-1. A number of these stakeholders have already been incorporated into the steering committee for the MWF, which includes several government stakeholders as well as some private sector and civil society representatives. Further description of some of the most important stakeholders to the fund and the role they might play in contributing to its implementation is presented below the table.

Table 10-1: Analysis of relevant stakeholders to the Mombasa Water Fund

Ministry/stakeholder type	Stakeholder	Interest	Influence	Priority
National Government Ministries and Agencies	Ministry of Water, Sanitation and Irrigation	**High:** Catchment management a key mandate of the Ministry (shared mandate with e.g. MoEF). Has drafted policy requiring 5% of project costs to be set aside for conservation.	**High:** Focus is on policy formulation and coordination. Involved in catchment management through collaboration with more local level bodies (e.g. county governments, WRUAs) and is attempting to expand collaboration with the private sector. Is the implementing agency for KWSCRP 2.	Work with
	Ministry of Environment and Forestry	**High:** Mandate includes rehabilitation, restoration and management of the environment, including catchment restoration. Has supported various PES initiatives. Has been engaging with donors to support catchment conservation in Mwache.	**High:** Implement catchment conservation programmes, often with a focus on addressing land degradation. Recipient of government and donor funding to support conservation work. Develops and enforces environmental regulations. However, noted a need for a more enabling regulatory framework to allow the Ministry to provide financial and technical support to the MWF.	Work with
	Water Resources Authority	**High:** National authority mandated with regulating and managing water resources in the country. Collaboratively undertakes catchment management and planning in Mwache Catchment with CDA	**High:** Has dedicated funding for catchment management from levies, oversees formation of WRUAs and conducts marking and pegging of riparian land. However, funding for catchment management said to be insufficient.	Work with
	Water Services Regulatory Board	**High:** National authority mandated to protect the rights of water consumers. Stated interest in encouraging utilities to contribute more to catchment conservation, now considers	**High:** In charge of setting water tariffs in consultation with country governments. Willing to approve tariff changes if counties can	Work with

		catchment conservation costs when approving tariffs.	document proposed catchment conservation activities	
	Water Sector Trust Fund	**Moderate:** Primary interest is financing the development and management of water services in underserved areas but does also fund catchment management, with a focus on capacity-building and funding of WRUAs and community forest associations.	**Moderate:** Potential funder, particularly for improving the capacity of WRUAs to carry out catchment conservation activities as well as support of community forest associations.	Obtain support
	Kenya Forest Services	**Medium:** Tasked with conservation and sustainable use of forest resources, aims include increasing forest cover. Functions include assisting county governments with forest development on private and community lands.	**Medium:** Limited coverage of gazetted forests in Mwache Dam catchment, but KFS has been providing expertise and seedlings in support of reforestation efforts in the area.	Obtain support
Regional Government Agencies	Coast Development Authority	**High:** Major funder of the Mwache Dam project, heavily involved in catchment management activities in the dam catchment, highly concerned by sedimentation issues	**High:** Has experience and expertise and a working model for conducting catchment conservation interventions in the region, including soil conservation measures and riparian pegging.	Work with
	Coast Water Works Development Agency	**High:** Core mandate is water and sewage infrastructure development but forced to maintain the coast bulk water system in the absence of a joint authority to take over management. Responsible for downstream work around Mwache Dam, including treatment plant and transmission infrastructure, so operations will be affected by sediment and water quality issues.	**Low:** Maintains the bulk water supply infrastructure but mandate does not extend to catchment management	Obtain support

Local Government	Mombasa County Government	**High:** Very concerned with water scarcity, wants to explore all avenues to address the challenge.	**High:** Potentially a major contributor to the fund as a means to securing the city's water supply. Recipient of donor funding, including an existing credit line from AFD. Also has a water act which could potentially be amended to integrate the water fund.	Work with
	Mombasa Water Supply and Sanitation Company	**High:** Under great pressure to improve water supply in Mombasa, view upstream management as a possible solution. Interested in securing supply from both Mwache Dam and Mzima Springs.	**Moderate:** Lacks funding to provide financial support to the fund. Can lobby for a revised water tariff from WASREB if planned catchment conservation activities are documented. Maintains water reticulation infrastructure within Mombasa and has received donor funding to improve this. Has intimate knowledge of water supply issues.	Work with
	Kwale County Government	**Moderate:** Largely interested as a seller of catchment management services, but also some interest as a buyer since Kwale is set to use some of the water from Mwache Dam for irrigation. Potential for livelihood benefits for residents of the country from MWF interventions.	**High:** Large portion of the Mwache Dam catchment, including most of the areas requiring intervention, are located in Kwale County. Potentially a key implementing partner, as catchment conservation is a county government mandate under Water Act 2016.	Work with
	Taita Taveta County Government/TAVEWO	**Moderate:** Potentially a seller of services for Mwache Dam. Concerned about environmental degradation, particularly in the Mzima Springs recharge area, potential buyer of services from Makueni here. Potential for livelihood benefits for residents of the country from MWF interventions.	**Moderate:** Contains a large portion of the Mwache Dam catchment, mostly maintained in a good state. Has set up some conservation programmes. Willingness to contribute to the fund if it helps increase water supply to Taita Taveta.	Obtain support

Research Organizations	Kenya Agricultural and Livestock Research Organization	**Moderate:** Interest limited to farmland interventions, which are in line with their objectives of improving productivity and food security.	**Moderate:** Could provide valuable technical advice regarding proposed interventions on farmland and selection of the most appropriate measures, including use of emerging technologies.	Obtain support
	Kenya Forestry Research Institute	**Moderate:** Its current strategic plan includes generating woodland rehabilitation technologies and the establishment and management of trees on farms.	**Moderate:** Could provide valuable technical support for agroforestry interventions as well as efforts to rehabilitate degraded woody habitats.	Obtain support
Non-governmental and community-based associations	Water Resource User Associations	**High:** Community-based associations for collaborative management of water resources, sub-catchment management plans include measures to reduce soil erosion. Have local knowledge of catchment degradation issues and potential solutions.	**Moderate:** No capacity to contribute to the fund financially but could be important for sensitising communities and implementing conservation interventions at the local level and could also play a role in monitoring the success of interventions.	Obtain support
	Platform for Land Use Sustainability – Kenya	**High:** Performs training, facilitation and demonstration of sustainable land use innovations, including rehabilitation of degraded land and soil and water conservation on farmland	**Moderate:** Potential implementing partner familiar with a number of the proposed fund interventions, with a particular focus on the use of Vetiver grass both on and off farmland (e.g. in riparian areas, gullies and other degraded land)	Obtain support
	Taita Taveta Wildlife Conservancies Association	**Low:** A number of ranches fall within the upper Mwache Dam catchment, potential service provider through maintaining healthy habitat in this region	**Moderate:** Currently ensure the maintenance of good vegetation cover in upper parts of the catchment	Inform
Business/private sector companies and associations	Kenya National Chamber of Commerce and Industry	**Moderate**: Membership-based association to promote the commercial and industrial interests of the Kenyan business community. Individual members working in the Mombasa region may	**Moderate:** Could be useful for raising awareness and encouraging investment in the MWF among its large membership.	Obtain support

		have an interest in securing improved water supply		
	Coastal Bottlers/Coca-Cola	**High:** Concerned by water supply situation in the region, view it as business risk even though they currently have sufficient water from their own boreholes	**High:** Coca-Cola has been heavily involved in supporting catchment conservation worldwide. Believe the MWF can be pushed in the name of business sustainability and as a way of replenishing the water used by Coca-Cola. Large and powerful company which could help champion the cause.	Work with
	Kenya Coast Tourism Association	**High:** Tourism establishments highly impacted by water and sanitation issues in Mombasa. KCTA advocates for a sustainable business environment and economic growth, including environmental sustainability.	**Moderate:** Hotels are major users of water. Largely reliant on boreholes are not a reliable solution, likely to be highly interested in securing water supply through catchment conservation. However, ability to provide financial support limited, especially post-COVID 19. KCTA can help lobby and raise awareness.	Obtain support
	Bamburi Cement/Lafarge	**Moderate:** Major producer of cement which consumes considerable amounts of water (around 5 000 m^3/day in 2016), largely reliant on boreholes. Sustainability targets include the desire to have a positive impact on water resources in water-scarce areas. May also have an interest in securing water supplies from a business risk perspective.	**Moderate:** Does not appear to fund major water-related projects at present but could be an important contributor to the MWF as a large company and water user. Has funded small-scale restoration projects.	Obtain support
	Kenya Association of Manufacturers (Centre for Green Growth and Climate Change)	**Moderate:** Represents manufacturing and value-adding industries, recently formed a Center for Green Growth and Climate Change	**Moderate:** Organises expos and awards to increase awareness and recognize best performing industries (though focus appears to be on energy efficiency), seeks to promote investment in green growth and promote best	Obtain support

		to deepen industries' commitments to energy efficiency and the circular economy.	practices in industry. Could be useful as a one-shot entry point into the manufacturing industries.	
Donor Agencies and other potential funders	The Nature Conservancy	**High:** Major implementer of water funds throughout the world, identified the opportunity to establish the MWF following the success of the UTNWF.	**High:** Initiator and source of crucial seed capital for water funds elsewhere in Kenya and on the African continent. Will be a key organization for starting the fund and raising support for it.	Work with
	Agence Française de Développement	**High:** Identified the opportunity to establish the MWF in partnership with TNC. Funder of the water treatment plant for Mwache Dam.	**High:** Has already contributed significant funding for the water treatment plan for Mwache and other water-related issues in the region. Support to the MWF could be a way of ensuring the long-term sustainability of these investments.	Work with
	International Fund for Agricultural Development	**High:** Has funded a range of projects in Kenya in support of smallholder farmers and improved agricultural practices, including increased recent focus on farmers in ASALs targeting poor, food insecure rural households. Incorporates grants to fund forest, rangeland and watershed management plans.	**High:** Major funder in the Kenyan agricultural sector. Currently funding the Kenya Cereal Enhancement Programme Climate Resilient Agricultural Livelihoods Window project, which includes Kwale, Taita Taveta and Kilifi counties (2022 end date).	Work with
	World Bank	**High:** As the major funder of the Mwache Dam project, it has a high interest in managing sedimentation issues in the catchment to extend the lifespan of the dam, as shown by its support for catchment management under KWSCRP-II	**High:** Already heavily involved in water-related issues in the area. The catchment management work it has already funded under KWSCRP-II could be upscaled through the MWF.	Work with
	United States Agency for International Development	**Moderate:** Projects incorporate improving nutrition and food production as well as improving water security, access and sanitation.	**High:** Large funding agency. Has mobilized significant funding for water service provision	Satisfy

		Focus appears to be more on water service provision but does have an interest in water source protection and increased linkage of WRUAs and WSPs.	through the Water, Sanitation, and Hygiene Finance (WASH-FIN) project (2022 end date).	
	Food and Agriculture Organization	**Moderate:** Seeks to support farmers to improve their productivity, improve food security in an environmentally sustainable manner. Also interested in building cooperation between government and its partners to implement agricultural initiatives.	**High:** Major donor funder in the agricultural sector with a well-established extension and field school network. Potentially an important funder of interventions on farmland, as well as a provider of advisory services.	Satisfy
	Caterpillar Foundation	**High:** Much interest in investing in natural infrastructure, including ecosystem restoration, catchment management and riparian rehabilitation. Reflected in support to the Upper-Tana Nairobi Water Fund.	**High:** Well-established track record in investing in ecosystem and water-related projects. However, it may have a more limited budget than some of the larger financing and donor organisations.	Work with
	Global Donor Platform for Rural Development	**Moderate:** Large network of development agencies, international financing institutions, intergovernmental organisations and foundations. Seeks to promote investment in agriculture and rural development	**High:** Potential one-stop port of call for raising awareness of the MWF among a range of organisations who might consider contributing to the project	Satisfy
	Aga Khan Development Network	**High:** Has been active in working on rural livelihoods in the Coast Region through the Coastal Rural Support Programme. Activities have included soil and water conservation measures	**Moderate:** Potential funder as well as a possible implementation partner. Its efforts to improve agricultural practices have reached a large number of rural households in the Coast Region.	Obtain support

POTENTIAL ROLE OF KEY STAKEHOLDERS IN THE MWF

NATIONAL GOVERNMENT MINISTRIES

At the national level, various government stakeholders are of high relevance to the fund. The proposed interventions aimed at improved land management fall within the mandate of both the Ministry of Water, Sanitation and Irrigation (MoWSI) and the Ministry of Environment and Forestry, both of which have a shared mandate of catchment management and conservation. While these ministries may not be directly involved in much catchment conservation on the ground, they could play an important role in providing and attracting funding as well as ensuring an enabling policy and legislative framework for the fund. As the overall implementing agency for the Mwache Dam project, MoWSI also has a high vested interest in catchment interventions to extend the lifespan of the dam through reducing sedimentation.

WATER RESOURCES AUTHORITY

The Water Resources Authority (WRA) will be another key national stakeholder, as they undertake catchment management in collaboration with other agencies and have a dedicated water usage levy which is meant to be put towards catchment management. This funding source could be used to support catchment conservation interventions undertaken as parts of the MWF. However, not all water service providers are paying this catchment management levy to the WRA (Peter Njaggah, WASREB, pers. com; Ahmed Mbarak, WRA, pers. com). The WRA is also mandated to monitor water quality and quantity and is currently engaging in efforts to develop sampling sites for sediment and other water quality parameters in the Mwache Dam catchment (Mbarak, WRA, pers. com). The WRA is thus the obvious partner for developing further water sampling stations, which will be essential for monitoring and evaluation of the impact of the proposed soil conservation interventions on water quality and quantity. The WRA also conducts marking and pegging of riparian land. Given that riparian protection and rehabilitation are a key proposed intervention under the MWF, the WRA could provide valuable advisory services regarding these interventions, with a potential for their activities to be integrated into and upscaled as part of the fund.

WATER SERVICES REGULATORY BOARD

Although the Water Services Regulatory Board (WASREB) has limited direct involvement in catchment management, their support could be essential to the fund from a regulatory perspective. This is because they will need to approve any changes to water use tariffs in support of catchment conservation activities, which could be an important source of funding for the MWF. Furthermore, WASREB is increasingly supportive of catchment conservation activities, as it incorporates upstream catchment conservation into license revisions and allows for a funding component for upstream conservation activities to be integrated into the tariffs charged by WSPs (Njaggah, WASREB, pers. com). As the primary beneficiary of water from Mwache Dam, MOWASSCO would be a potential candidate for submitting a tariff review to WASREB to incorporate the cost of catchment conservation activities. Alternatively, conservation activities could be incorporated into the bulk water tariff. This tariff component could then be added to the MWF in support of the proposed catchment conservation activities. WASREB will only approve tariff changes if proposed conservation activities can be clearly described. In this regard, the MWF could play a valuable coordinating role in ensuring that any tariff revisions in support of catchment conservation translate into conservation activities in the upstream counties. Despite the opportunity for catchment conservation to be incorporated into tariffs, there appears to be a lack of awareness around this among WSPs (Njaggah, WASREB, pers. com). Indeed, MOWASSCO indicated some reluctance to institute a catchment conservation levy at the county level, suggesting that it would be simpler to support catchment conservation through levies collected by WRA or WASREB (Njaramaba, MOWASSCO, pers. com). The MWF could again play a coordinating role here by increasing engagement between WASREB and county government WSPs on the integration of environmental protection into their tariffs. Nevertheless, it must also be remembered that WASREB's core mandate is to protect the rights of water consumers, Hence, they will be unlikely to accept a situation where the bulk of catchment conservation costs are placed on water consumers, highlighting that the MWF should not be overly-reliant on increasing water tariffs as a funding source. This is especially the case given that water tariffs in Mombasa are already some of the highest in the country (Rural Focus Ltd, 2020).

COAST DEVELOPMENT AUTHORITY

At the level of regional governance, the Coast Development Authority (CDA) is a key stakeholder for the fund. As a major funder of the Mwache Dam project, the CDA has a large interest in addressing the threat of sedimentation to the lifespan of the dam. In this regard, it has been conducting catchment rehabilitation activities as part of the catchment management component of the World Bank-funded KWSCRP-II project. Through this process, they have gained valuable experience regarding the success, effectiveness and social acceptability of the various conservation interventions they have attempted in the catchment, as was evident in discussions with Dr Mwanasiti Bendera of the CDA. This includes various interventions proposed as part of the MWF, such as terracing, tree planting, gabion construction and riparian rehabilitation, marking and pegging. They can thus provide a valuable advisory service to the MWF on these interventions and have expressed their willingness to avail their expertise to the fund (Bendera, pers. com). According to Bendera (pers. com), there remains a need to upscale the interventions that are ongoing as part of the KWSCRP-II project to fully address soil erosion issues in the catchment, and she expressed the hope that a mechanism like the MWF could be used to fund this.

COAST WATERWORKS DEVELOPMENT AGENCY

The Coast Waterworks Development Agency (CWWDA) has limited scope to contribute directly to the water fund, since its core mandate is the development of water and sewerage infrastructure. However, its operations could be significantly affected by the health of the Mwache Dam catchment, since it will be responsible for development of the water treatment works. High loads of suspended solids and other pollutants could have a significant impact on water treatment costs, meaning that the CWWDA has a clear vested interest in catchment conservation, especially until the joint county authority is formalized and can take over operation of the bulk water system from CWWDA. The CWWDA could thus play an important role in using its influence to advocate for the MWF and the catchment conservation interventions it proposes.

COUNTY GOVERNMENT OF MOMBASA AND MOWASSCO

Of the WSPs in the Coast region, the County Government of Mombasa and the Mombasa Water Supply and Sanitation Company (MOWASSCO) have the greatest interest in sustaining water supply from Mwache Dam, given that Mombasa is set to be the major recipient of water from the dam, which will become the major future source of water in the city. Due to this and the severity of the ever-worsening water supply issues the city currently faces, Mombasa County thus arguably has the most pressing interest of any stakeholder in sustaining future water supply from Mwache Dam through catchment management activities. However, as the entirety of the dam catchment lies outside its area of jurisdiction, the Mombasa County Government cannot directly conduct catchment conservation activities itself. Its role is thus limited to providing support to the MWF to conduct catchment management activities in the neighboring counties. Given the importance of the dam to the city's water supply, Mombasa County would be expected to be one of the major supporters of the MWF. However, financial constraints may limit the ability of the county to contribute directly to the fund, particularly in the case of MOWASSCO. According to Njaramba (pers. com), MOWASCCO is currently hamstrung by a lack of funding and is struggling to maintain just its existing infrastructure. However, MOWASSCO and the county government already receive significant funding from development partners and donors to support improvement of the city's water supply. They could thus play an important role in helping to attract donor funding for the MWF, given the seriousness of the city's water supply situation and their position at the forefront of the issue. As has already been noted, the county could also apply to WASREB for a revised water use tariff which takes into account the cost of catchment conservation. The funds generated through this tariff could be used to support catchment conservation activities undertaken as part of the MWF. However, this might not be a particularly appealing option politically. Consumers may resent any tariff increase, especially when they are already not receiving a reliable supply of municipal water. Additionally, water tariffs in Mombasa are already some of the most expensive in Kenya (Rural Focus Ltd, 2020). Furthermore, the sedimentation of Mwache Dam would be a slow and gradual process which exceeds the length of election cycles, which could further reduce the incentive for the county government to pursue potentially unpopular funding mechanisms such as tariff increases.

KWALE, TAITA-TAVETA AND KILIFI COUNTY GOVERNMENTS

As the entirety of the catchment falls outside of Mombasa County, it will be important to gain the support of the County Governments of Taita-Taveta, Kilifi and, in particular, Kwale. The focus on Kwale is because the majority of proposed conservation interventions are located here, due to both its proximity to the dam site and the high erosion sedimentation risk from a number of areas in the county. In contrast, Taita-Taveta is less of a priority for intervention as it is located further upstream of the dam site, with much of the county flat and under good vegetation cover (particularly in the conservancies). Meanwhile, the portion of the dam catchment falling within Kilifi is very small. Nevertheless, it will be important to gain support for the fund from all the counties in the catchment to avoid inter-county resentment and competition, even if Kwale will be the focus for interventions. The county governments have an important role to play in supporting and facilitating catchment rehabilitation activities within their areas of jurisdiction. While the CDA is currently conducting various catchment rehabilitation interventions as part of the KWSCRP-II project cycle, their mandate does not specifically concern water resources management but rather encompasses planning and coordinating development projects across the Coast Region more broadly. As a result, the county governments might be a better long-term choice as implementation partners for most of the activities proposed under the MWF. Indeed, conservation of water catchments is now a county government responsibility under the Water Act 2016. In Kwale for example, the interventions proposed for farmland would fall under the mandate of the Kwale County Government Department of Agriculture, Livestock and Fisheries, while interventions such as sustainable natural resource management would fall under the mandate of the Department of

Environment and Natural Resources. Money generated by the fund could be channeled to these county government departments to undertake the proposed interventions. Some of the proposed MWF interventions also have the potential to bring livelihood benefits to Kwale and the other upstream counties, such as through increased agricultural production. This could be used as a selling point of the MWF to the county governments.

ROLE OF THE PRIVATE SECTOR

Support from the private sector could also be important for improving the financial viability of the MWF. In this regard, we have identified some large, individual companies which could play an important role in supporting the fund, as well as business associations which could provide a single point of entry for raising awareness of the fund among member companies. Coastal Bottlers Limited/Coca-Cola, a major user of water in the region, have been identified as one such company. While the company is largely reliant on its own boreholes as a water source, it has expressed interest in supporting efforts to secure water supply through the MWF from a business risk perspective. For example, legislation around the use of borehole water could change in the future, especially if heavy usage by companies like Coastal Bottlers Limited/Coca-Cola draws the water table down to the point that surrounding communities can no longer access water with their own boreholes. This also reflect poorly on the brand's reputation. Hence, supporting initiatives like the MWF, which could help diversify and sustain the sources of water available to the company, is potentially attractive from a business risk perspective. Coca-Cola internationally has also been extensively involved in supporting watershed conservation activities, showing that the company is already well on board with the concept. Although data on water users in Mombasa is very scarce, Bamburi Cement appears to be another major private sector water user in the area who might have similar interests in supporting the MWF to Coastal Bottlers/Coca-Cola. In addition, the Kenya Manufacturers' Association and Kenya National Chamber of Commerce and Industry were identified as stakeholders that could be used to raise awareness and support for the MWF among other companies. The former association in particular appears to have an increased interest in sustainability and green growth, as evidenced by its creation of a dedicated Centre for Green Growth and Climate Change. The Kenya Coast Tourism Association (KCTA) and its membership also potentially have a high interest in supporting the MWF, given the costs and challenges tourist establishments face as a result of water scarcity in the region.

NEW BULK WATER AUTHORITY

Plans for the formation of a new bulk water authority to take over management of the bulk water supply system from CWWDA, in line with the provisions of the Water Act 2016, have existed for some time. This authority will comprise representatives from the various counties supplied by the coast bulk water system. According to Tsuma (pers. com), the formation of the new joint authority is still under adjudication by the MoWSI. Although the inception of this new joint authority has suffered numerous delays, it is reportedly close to becoming a reality (Kihara, pers. com). As a single body which unifies all upstream and downstream counties, the joint authority would have a key role to play in the MWF. Given that competition and animosity among counties around water supply issues could be fierce, it could play a valuable role in reducing conflict and facilitating collaboration among counties, as will be essential for the successful implementation of the MWF. As would be the case for CWWDA, a reduction in the storage capacity of Mwache Dam due to sedimentation would have a direct impact on the revenues the bulk water authority could generate from water sales to Mombasa and Kilifi counties. Additionally, the joint water authority could end up being responsible for the high costs of sediment clearing from the proposed check dams. These costs will be directly related to the health of the catchment and the amount of sediment being exported from it. It would thus be in the authority's financial interest to support the fund as much as it can. Integration of catchment conservation costs into the tariff it charges counties for bulk water supplied form Mwache Dam could be a potential source of funds for the MWF. As has already been noted, this would require the approval of WASREB, who in principal support the integration of upstream conservation activities into tariffs. While we have also discussed the possibility of integrating catchment conservation into tariffs charged by MOWASSCO, anchoring the tariff at the level of the bulk WSP could be fairer and less contentious. This is because it would result in counties contributing to the fund in direct proportion to the amount of water they use, providing an objective way of determining how much individual counties should contribute to the MWF.

PART V. IMPLEMENTING THE MWF

11 FINANCING AND IMPLEMENTING THE MWF

FINANCING THE MWF

The MWF will have the ability to receive, generate, manage and spend funds through endowment and revolving facilities[181], as well as to guide aligned public investment for financing the above interventions. Funding would be provided by domestic and international donors and water charges, and ultimately also from interest from the endowment fund. Public and private investment may also take the form of non-monetary actions that are aligned with the MWF, such as staff assignments to undertake MWF activities in the designated water source areas, or legal assistance.

It is estimated that the average total annual budget that the MWF will need to carry out its mission effectively and efficiently will be approximately US$8.8 million. Interventions in the Mwache catchment would require an initial expenditure of US$6.4 million followed by annual payments of US$2.2 million, while those in Mzima Springs recharge area would require a smaller upfront investment of US$2.1 million but much higher ongoing payments of US$6.3 million per year. The origination and establishment costs which include costs for the MWFs financial, legal and institutional structuring are estimated to be in the region of US$300,000. The annual costs[182] can be expected to be in the region of US$275,000 per year.

Given the size of the overall investment required, it is likely that the MWF would need to aim to raise an initial sum, say $20 million, which could generate a net average annual income of about US$1 million (based on the 5% spending policy[183]), and through demonstrating the success of initial endeavors, obtain further commitments over time. Future funds could also be pledged conditional on measure of success.

The protection of investments in water security is the main purpose of the MWF. As such, the primary beneficiary is the State, more specifically its organs responsible for raw water supply infrastructure. Therefore, there is strong motivation for a contribution from the sale of raw water, some or all of which could be passed on to the county government water service providers. A modest KSh2/kl catchment conservation levy could generate annual revenues of US$1.3 million for expenditure on MWF activities in Mwache Dam catchment and US$0.7 million per year for Mzima Springs recharge area. This would also greatly encourage co-funding by other national and international stakeholders. For example, The World Bank as funders of the Mwache Dam, will be interested in the protection of their investment. Indeed, initial expenditure for effective intervention in the Mwache Dam catchment (US$6.4 million) represents just ~3% of the US$200 million dam development cost.

Furthermore, it is also envisaged that some funders e.g., motivated by carbon, biodiversity or other gains, might need to see ringfenced funding "pots" for specific projects, such as the

---

[181] For example, the revolving fund could provide a vehicle to prepare the groundwork while raising capital for the endowment fund, e.g., by funding the immediate initiation of priority interventions while the endowment is being capitalized

[182] The MWF's annual costs are expected to include salaries, vehicles, office rent and equipment, marketing and communications, training, audit and miscellaneous costs.

[183] Broadly adopted by most US NGOs and charitable foundations as a sensible baseline for spending, a 5% spending policy means an organisation must achieve a return of 5% plus the rate of inflation to support the organisation in perpetuity.

Chyulu Hills water PES scheme. Implementation of the Chyulu Hills PES could be relatively straightforward given the already operational Chyulu REDD+ Project through which it will operate. However, revenues from the recommended KSh2/kl water charge (US$0.7 million per year) for water supplied from the Springs would cover only a small portion of the annual payment. Significant amounts would need to be fundraised to increase the endowment or be received through grants and donations to cover the costs of the PES scheme fully. This is not an impossible feat given the rich biodiversity of the landscape and the significant existence and bequest values attached to it.

IMPLEMENTATION MODELS

Implementation of the restoration and conservation activities can be undertaken using different types of incentive and assistance-based approaches. We propose a range of complementary and mutually-supportive types of assistance to be funded in order to bring about the land and resource management interventions required in different parts of the two priority water source areas. These include, but are not necessarily limited to, the following:

- ***Direct assistance to farmers*** in Mwache catchment to implement and maintain soil conservation measures, by the Kwale County government and with the assistance of an NGO;
- ***Establishing and financing environmental restoration teams*** which comprise trained core personnel and locally employed labor to undertake vegetation restoration and rehabilitation measures, particularly in the Mwache Dam catchment;
- ***Setting up payments for ecosystem services (or PES-like schemes)*** in the Mzima Springs recharge area (Chyulu Hills water PES scheme) and Mwache Dam catchment (within the western pastoral/conservancy landscape) to incentivize the restoration and maintenance of woody resources and rangeland ecosystem health; and
- ***Encouraging and assisting with the establishment of new conservancies*** and other community or landowner associations that might be incentivized by and able to benefit from PES-type funding or other opportunities in both water source areas.

The way in which these projects are designed and implemented is key to their success.

DIRECT ASSISTANCE TO FARMERS

The farmer assistance model seeks to emulate the success of large-scale soil conservation programs combining government extension staff, donor agencies and NGOs in other parts of Kenya. For example, successes in Machakos County under the National Soil and Water Conservation Programme show the potential for large-scale adoption of terracing and other soil conservation measures given adequate training, extension support and tools for local farmers. Following multiple soil conservation programs in Machakos, over half of all arable land and 83% of land in hilly areas had been adequately conserved by 1985 (Mortimore & Tiffen, 1994). About half of this growth was attributed to unassisted farmers who spontaneously adopted conservation measures following their general success in the region. In the Mwache Dam catchment area, the Kwale County Government's Agriculture department would be best placed to take the leading role in helping farmers to set up their terraces and associated measures, through extension services and direct support in terms of assisting farmers with earth works and other labor-intensive work. Grants could also be provided to

NGOs with relevant expertise and interests, to either directly assist farmers themselves or to work in partnership with the county government. Numerous NGOs in Kenya currently provide assistance and training to farmers around similar interventions to those proposed under the MWF. Additionally, the CDA has worked extensively with farmers to reduce soil erosion as part of KWSCRP-2 project and could thus provide valuable advisory support to the MWF from their experiences to date.

RESTORATION PROGRAMME

It is recommended that the direct rehabilitation of badly degraded areas is undertaken by trained restoration teams. It would not be feasible to expect widespread adoption of these practices among communities. However, the program should be designed to use local laborers, so that the activities create employment. This program should maintain a long-term business relationship with the local laborers to ensure that the planted vegetation survives and thrives. Training support could be provided by staff from government agencies with relevant expertise. These potentially include the environmental departments of county governments and staff from the CDA and WRA with recent experience conducting rehabilitation activities in the Mwache Dam catchment. Additional technical support could be provided by NGOs such as Vetiver Network International or companies with expertise in land restoration.

A range of potential partners could provide technical expertise to assist with the specific design and planning of restoration interventions and to provide training to the restoration teams. Staff from the upstream county governments, particularly from the Environment and Natural Resources departments, could again be seconded to the fund to provide training in this regard. The CDA and WRA also have experience conducting rehabilitation efforts in the catchment, including in degraded riparian zones. Staff from these organizations could thus also be well placed to provide training to restoration teams. These interventions also align with the expertise and interests of KFS and KEFRI. The KFS has also been involved in providing seedling in support of restoration initiatives in the area. Finally, various NGOs with expertise in land restoration interventions in Kenya could also provide valuable technical expertise and assistance with training and could be provided with grants by the MWF. For example, the Platform for Lan Use Sustainability Kenya (PLUS-Kenya) is an NGO which has been active in training farmers on the use of Vetiver grass to restore gullies, bare areas, mines and other degraded lands, as well as to protect and stabilize degraded riparian areas. They are also a major supplier of Vetiver grass seedlings.

PAYMENTS FOR ECOSYSTEM SERVICES AND ESTABLISHMENT OF NEW CONSERVANCIES

In the Mzima Springs recharge area and Mwache Dam catchment area, PES (or PES-like schemes) could be used to incentivize the restoration and maintenance of woody resources and rangeland ecosystem health (as part of the sustainable natural resource management intervention which involves incentives to reduce overgrazing and control overharvesting of fuelwood in degraded areas). In such a PES scheme, the buyer would by the MWF, acting on behalf of the water beneficiaries. PES schemes are one of the few options available to leverage an improvement in catchment management. The use of PES may in fact provide a stimulus (the financing required) for the development of conservation areas through the establishment of new conservancies and other community or landowner associations. In the northern part of the Mwache Dam catchment a large block of natural vegetation that lies between the Tsavo East National Park and the Shirango conservancy has been identified as a potential site for the establishment of a community wildlife conservation area.

Within forest, woodland or bushland areas, the primary aim of a PES scheme or wildlife conservancy would be to reduce the rate of woody vegetation loss due to unsustainable harvesting or clearing for agriculture and encourage vegetation recovery. It would also discourage overgrazing and encourage the maintenance of grass cover. Within the Mzima Springs recharge area, woody vegetation cover and biomass can be easily and objectively measured using satellite data. Indeed, there is already a robust forest and vegetation monitoring program in place as required under the VCS VM 009 methodology under which the REDD+ project is accredited. Within the Mwache Catchment, monitoring and measuring ecosystem condition will need to include on-the-ground field surveys which are already undertaken on the Wildlife Works Kasigau Corridor REDD+ Project ranches. The PES-like scheme could also focus on riparian areas, a primary aim being to create and maintain riparian setback areas that are free of cultivation and resource use, where natural vegetation can re-establish itself, as well as to protect these areas from activities that lead to erosion, including unmanaged watering of livestock and sand mining. The outcome would be easily and objectively measured using satellite data.

Given that PES schemes have been implemented in Kenya with mixed success, it is important that institutional pre-requisites and key design elements are properly addressed (see Box 4). The important set of institutional pre-requisites is that the communities involved are well defined with clear, trusted leadership, and have a well-defined, designated conservation area under their control. The important set of design elements is that the measurement of conservation outcomes is determined and executed by an independent party and is well understood by the communities, and that the payments are conditional on conservation outcomes, and are high enough to incentivise the practices that lead to these outcomes. In the absence of a strong community structure or secure land tenure in this landscape, it is recommended that communities (not too large) are invited through a roadshow to organise themselves and bid to opt into the PES scheme. This will avoid having to work directly with individual farmers in the group. Given that local leaders have been benefitting from active deforestation, the scheme design will need to ensure that they will gain more from ensuring protection. The communities that share common grazing areas may also be encouraged to cooperate with one another. Participating communities could be given exclusive rights to harvest sand, for example, on condition that it came from one designated site that is managed according to strict environmental protocols.

For the Chyulu Hills landscape, the MWF can build on existing institutional, governance, financial management and operational capacities through the existing REDD+ project. However, it is recommended that a strong element of conditionality is introduced.

Box 4. A summary of the key factors that contribute to the success of PES projects or programmes in tropical, developing country, communal tenure contexts

Biophysical factors critical for achieving outcomes

- The ecosystem to be managed/restored is not degraded beyond repair and has a reasonable prospect of attaining a meaningful level of ecological connectivity and ecosystem service provision;
- Environmental outcomes are measurable;
- Very good baseline data against which outcomes can be monitored;
- Research supports clear links between service provision and land management practices; and

- Scale of the intervention is large enough to have a measurable effect.

Institutional factors critical for achieving outcomes

- Service provider community is well defined and stable;
- Clear and uncomplicated land tenure and property rights;
- The community needs to have a well-respected, fair and transparent institution that can negotiate on their behalf (e.g. CBO or trust);
- Simple, efficient organisational structure
- A strong institutional framework enabling funding flows and distribution, with safeguards (e.g. benefit sharing rules, legal grievance resolutions);
- There is a competent intermediary who facilitates engagement between all actors (civil society, government, private sector) and provides external financial oversight;
- An established rapport and trust between beneficiaries, service providers and intermediaries;
- Effective and comprehensive monitoring and evaluation system executed by an independent body;
- Payment is subject to strong conditionality rules;
- Supportive public institutions, policies and laws;
- Presence of an institutional champion;
- Strong capacity among key actors, including government capacity for relatively swift development of legal frameworks and pilot projects; and
- A design that aims to minimise interannual variability in payments in a compliant system.

Economic factors that encourage buyers/investors:

- Demonstrating clear threat or risk to provision of ecosystem services of high value;
- Low opportunity costs to secure their provision;
- A strong business case showing that benefits exceed costs;
- Meeting the abovementioned biophysical and institutional requirements;
- Equitable distribution of PES benefits and revenues;
- Improved developmental outcomes for the service providers;
- Clear definitions of the targeted ecosystem services/activities and how they will be measured and valued;
- Evidence of positive impacts of interventions;
- Access to initial capital for implementation (start-up costs of equipment, materials, etc);

- Realistic evaluation of beneficiaries' willingness to pay; for example water utilities, may already be paying statutory water fees to a regulating body, and may perceive contributing to the scheme as double payment; and
- Proximity to or a close connection with the location of service provision.

Socio-cultural factors that encourage service provision:

- High acceptability of interventions by local communities/farmers;
- Interventions improve human livelihoods and reduce poverty;
- Capacity building of service providers;
- Awareness raising and sensitizing service providers – this is critical for securing involvement;
- Complementary livelihood initiatives;
- Demonstration sites showing positive impacts of interventions on local livelihoods;
- Establishing trustworthy relationships between local communities, the intermediary and other stakeholders;
- Cooperative community-based approach;
- A history of positive outcomes;
- A good balance between outcomes for service providers (e.g. poverty alleviation) and beneficiaries (supply of ecosystem services). Overemphasis of local social outcomes can reduce intended conservation outcomes;
- Fairness arising from equitable access and inclusivity in decision making;
- An absence of social conflicts over land use;
- Benefits accruing to actual service providers exceed their opportunity costs;
- A system designed to avoid free riders or rent seekers.

POTENTIAL WATER FUND GOVERNANCE MODELS

A water fund is a funding and governance mechanism which provides sustainable funding for watershed conservation. It has demonstrated the potential to advance economic incentive mechanisms such as PES by serving as an instrument for financial administration and an intermediary between buyers and sellers of ecosystem.[184] Water funds mobilize and invest funds from urban water users and other donors, and re-grant to a range of stakeholders.[185] It also connects urban users of watershed ecosystem services to upstream land managers through a governing entity.[186]

[184] Annabelle Bladon, Essam Yassin Mohammed, and E. J. Milner-Gulland. 2014. A Review of Conservation Trust Funds for Sustainable Marine Resources Management: Conditions for Success. IIED Working Paper. IIED, London.

[185] Ibid

[186] Ibid

This analysis has considered various water fund governance models, including:

i) Multi-stakeholder public-private partnership model;
ii) Government-operated model;
iii) Civil society-operated model;
iv) Watershed Committee model; and
v) Private sector-operated model.

MULTI-STAKEHOLDER PUBLIC-PRIVATE PARTNERSHIP MODEL

A multi-stakeholder governance model aims to create a contractual partnership between civil society, public and private sector actors to govern a water fund. Under this model, a multi-institutional body comprising of contributing and/or non-contributing stakeholders makes decisions on how to use water fund revenue.[187] In this way, the model provides an institutional space for negotiation and collaboration among various stakeholders drawn from public agencies, civil society and private sector actors.

The contractual arrangement defines actors' relations and use of funds, and provides some level of transparency in terms of expectations, roles, responsibilities and obligations.[188] The multi-institutional body prioritizes the use of funds through investment of the water fund assets in financial markets and distribution of the resulting interest to finance specific watershed management and conservation interventions. In addition to the multi-institutional body or a board, a secretariat is usually established to provide technical support and implement Board's decision.

A multi-stakeholder model has been widely applied in many water funds in Latin America and Africa. In Quito, Ecuador, a water conservation fund – Fondo de Protección del Agua (FONAG) – is governed under a public-private partnership model.[189] It receives funding from government, public utilities, private companies, and non-governmental organizations. FONAG is governed by a Board of Directors comprised of water users that have contributed to the fund.[190] However, in other water funds, such as Procuencas in Zamora, Ecuador, non-contributing stakeholders such as the Ministry of the Environment are also represented in the Board.[191] Similarly, in the Cauca Valley in Colombia, non-contributing grassroot NGOs are represented in the Board.[192] However, in Tungurahua, Ecuador, the German Technical Cooperation Agency (GIZ) contributed financial resources in the name of indigenous communities in the watershed to ensure their representation in the water fund board.[193]

Water funds in Ecuador are increasingly being linked to other participatory decision-making organizations which incorporate a wide range of watershed stakeholders, including those that

---

187 Chan, K. M., Shaw, M. R., Cameron, D. R., Underwood, E. C., & Daily, G. C. (2006). Conservation planning for ecosystem services. PLoS biology, 4(11), e379. https://doi.org/10.1371/journal.pbio.0040379
188 Supra Note 172
189 Ibid
190 TEEBcase by V. Arias, S. Benitez, & R. Goldman (2010). Water Fund for Catchment Management. Ecuador. Available at TEEBweb.org
191 Supra Note 172
192 Ibid
193 Ibid

are not trust fund board of directors.[194] This has improved oversight for water funds, and provided a space for cooperatively setting priorities and designing projects that are financed through the trust funds.[195]

In Kenya, the Upper Tana Water Fund is governed under a multistakeholder model by the Board of Trustees, the Board of Management, the Advisory Committee and the Secretariat. The Advisory Committee comprises of representatives from the county governments and in-region national government agencies. Watershed stakeholders including Local communities are represented in the Water Fund by the Advisory Committee which has enhanced the space for collaborative management.[196] Private companies, national government departments and agencies and county governments are the main contributors to the Upper Tana Nairobi Water Fund.[197]

Kenya has put in place policy, legal and institutional frameworks to support implementation of public-private partnerships in various policy fields, such as natural resources management. The supporting governance instruments include the PPP unit established in 2009; the PPP policy statement adopted in 2011; the PPP Act (2013) and the PPP Node established at Ministry of Water, Irrigation and Sanitation; and the PPP Regulations (2014). Environmental policies and legislations, particularly those related to water, land, forestry and wildlife have incorporated PPP. These instruments lay emphasis in the formation of business-oriented partnerships to provide incentives for conservation through the creation of livelihood benefits. Whereas PPP has opened up participation of private sector, civil society and communities in conservation and management of ecosystem's resources, it is yet to gain traction in watershed conservation.

GOVERNMENT-OPERATED MODEL

A government-operated model vests decision-making power for the water fund in public authorities such as a national government agency or subnational authority. Under this arrangement, a fund committee comprising of representatives of relevant government agencies or local authorities act on behalf of water users to set up a water fund, raise revenue and negotiate voluntary agreements with upstream communities to engage in sustainable land use practices.[198]

Under a government-operated model, financing is mobilized from downstream beneficiaries through water fees or levies. Government-operated models have been applied successfully in Latin America. For example, in Pimampiro, Ecuador, the municipal government acts as the buyer of watershed environmental services on behalf of the urban water users.[199] To facilitate this arrangement, the Municipal government has passed an ordinance levying a 20 percent fee on drinking water to raise watershed conservation revenue.[200] A fund committee comprised of Pimampiro's Mayor and the directors manages the fund and negotiates voluntary

[194] Craig M. Kauffman (2014). Financing watershed conservation: Lessons from Ecuador's evolving water trust funds. Agricultural Water Management 145:39-49
[195] Ibid
[196] Interview with Fredrick Kihara, The Nature Conservancy Regional Director, 23 July 2021
[197] Ibid.
[198] Supra Note 179
[199] Supra Note 172
[200] Ibid

agreements with farmers to conserve and sustainably manage upstream catchment in exchange for cash payments.[201]

Similarly, a regional water fund, FORAGUA, was set up by several municipal governments to conserve and restore the environmental services provided by watersheds. This arrangement requires each municipal government to formulate its own ordinances that establish a fee on water use to finance local conservation and restoration projects.[202] This fee is collected monthly and transferred to the water fund trust.

Kenya's water law contains provisions that can facilitate the implementation of a government-operated water fund. Under the Water Act (2016), county authorities are mandated to provide water services and develop county water works. To exercise this mandate, counties are required to set up WSPs which should be commercially managed and licensed by WASREB. Similarly, the Water Act (2016) provides for WWDAs to develop and manage national public works' assets. The assets which include water storage and water works for bulk distribution of water services should be later handed over to the county or cross-county WSPs.

Besides water service provision, counties have a responsibility for catchment protection. This presents a compelling need for sustainable funding mechanisms to facilitate implementation of watershed conservation and source water protection measures. The county governments through WSPs can raise water tariffs to support watershed conservation and management interventions subject to approval by WASREB. Under the license conditions for commercially viable WSPs, water utilities are required to provide an estimate of the cost of catchment conservation, and apply to WASREB for such to be factored into the tariff. Currently, WSPs in Mombasa, Kilifi, Kwale and Taita Taveta are operating on expired tariffs.[203] However, Mombasa County already has some of the highest water tariffs in Kenya (Rural Focus Ltd, 2020). Hence, WASREB is unlikely to approve large tariff increase on Mombasa consumers who are already paying a relatively high amount for water, potentially limiting the degree to which tariffs on water consumers can support the proposed water fund activities.

The government has set up the WSTF as a as a financing institution to fund direct water service provision in marginalized communities and community-level initiatives for sustainable management of water resources. While the WTSF could be another potential source of funding in a government-operated model, the proposed water fund activities do not directly align with its current area of focus. Under the Water Act (2016), WSTF is mandated to provide conditional and unconditional grants to the county governments and finance water and sanitation services for the poor and underserved communities in rural and urban areas. Specifically, it provides funds for: (i) community level initiatives for the sustainable management of water resources, (ii) development of water services in rural areas considered not to be commercially viable, and (iii) development of water services in the under-served poor urban areas. Despite enlarging the scope for collaboration with county governments over water services, WRA and WRUAs over catchment management, and private investors over resource mobilization for onward lending to credit worthy utilities, WSTF's operational scope is limited to financing water and sanitation services for the underserved communities in rural and urban

[201] Ibid
[202] Ibid
[203] Interview with Peter Njaggah, Acting CEO, WASREB, July 12th 2021

areas. The Water Act (2016) would need to be amended for WSTF to operate as an endowment fund for watershed management.

CIVIL SOCIETY-OPERATED MODEL

Significant flows of funding for conservation are traced in the networks between civil society, governments and private markets.[204] These networks are utilized by the civil society to raise conservation finance. Apart from increasing income by attracting public funds from governments and aid agencies, CSOs have increasingly positioned themselves to influence and leverage both public and private finance.[205]

A civil society-operated model aims to create a voluntary alliance of conservation organizations, networks and donors to govern a water fund. Under this arrangement, a board of trustees drawn from CSOs with interests in line with fund's goals seeks to mobilize resources from various sources – including international donors, national governments and the private sector – and prioritize specific watershed management and conservation interventions for implementation through NGOs, CBOs and government agencies.[206] Besides the board of trustees, specialized committees and the fund manager are often in place to offer technical support. Depending on a particular country's legal system, CSO-operated water fund can be established through a Charter, Constitution, Articles of Incorporation, or Trust Deed.[207] These governance instruments define not only the purposes for which a trust fund may be used, but the composition, powers and responsibilities of the governing body.

Kenya has multiple registration frameworks available for CSOs. As such, CSOs are registered as NGOs, Societies, Community Based Organizations, Companies Limited by Guarantee or Trusts, and operated in diverse forms and structures.[208] Kenya has also developed an NGO Policy (Sessional Paper of 2006) that explicitly recognized NGOs as critical partners in social and economic development.[209] A CSO-operated water fund can be established under these existing legal regimes.

Despite their close association with communities and potential role in enhancing accountability and oversight, CSO movement is still weak in Kenya. Their growth is particularly undermined by weak capacity and sharp decline in conservation funding. The past decade has witnessed not only a sharp decline in donor funding, but increased hostility towards CSOs from the governments. The hostility is caused by their advocacy strategies which often bring to the mainstream media governance lapses on the part of the government. Although Kenya has a supportive policy and legal framework for CSOs, some laws have provisions that restrict the space in which CSOs operate. They tend to intimidate, suppress, and control CSOs and their activities, and restrict their ability to secure resources. This includes prohibitions against funding, requirements for advanced government's approval, and policies to route funding from

[204] Anyango-van Zwieten, N., Lamers, M. & van der Duim, R. (2019). Funding for nature conservation: a study of public finance networks at World Wide Fund for Nature (WWF). Biodiversity Conservation 28, 3749–3766 https://doi.org/10.1007/s10531-019-01848-y

[205] Ibid

[206] Conservation Finance Alliance (CFA) (n.d.). Practice Standards for Conservation Funds. https://static1.squarespace.com/static/57e1f17b37c58156a98f1ee4/t/5953eae486e6c0fb1c81cb93/1498671896001/CFA_Standards_full-compressed.pdf (Accessed on June 9, 2021)

[207] Ibid

[208] Kanyinga, K. & Mitullah, W. (2007). The Non-Profit Sector in Kenya: What we Know and What We Do Not Know, The Institute for Development Studies, University of Nairobi.

[209] Sessional Paper No. 1 of 2006 of Kenya

foreign sources through government. Despite these prohibitions, there is a growing need for cross-sector partnerships between the CSOs, government and private sector. The CSOs have strong ability to mobilize communities to participate in catchment conservation.

Currently, there is a sustained push for the CSOs to collaborate with both public and private sector entities to fast-track the realization of sustainable development agenda. This is based on a realization that the synergy between CSOs, private sector and government can foster sustainable development. The growth of global CSOs-public-private partnerships (CPPPs) for environmental issues, such as climate change, has opened up avenues for nonstate actors' participation in environmental governance. These movements are akin to the multi-stakeholder PPP model discussed earlier.

WATER RESOURCE USERS COMMITTEE MODEL

A water resources user committee aims to build a formal network of land owners and water users to manage the water fund. This model is applied in Brazil where river basin committees invest in bulk water user fees to sustain governance of the water fund.[210] Brazil's National Water Policy has set up a water-user fee, and created watershed committees to support watershed conservation.[211] The fundraising potential of these watershed schemes is significant. For example, one of Brazil's key watersheds could raise up to $25 million per year in water user fees.[212]

In Kenya, the national and county governments are involved in environmental and natural resources policies. However, the government share resource management responsibility with local resource users. Under the Water Act (2016) and Forest Conservation and Management Act (2016), community participation in water and forest governance are provided through Water Resource Users Associations (WRUAs) and Community Forest Associations (CFAs), respectively.

The Water Act (2016) has established a governing structure for watershed management comprising of WRA, BWRCs and WRUAs, and created water tariff system to support catchment conservation efforts. Bulk water users, such as water utility companies pay annual abstraction fees to WRA. Even though bulk water users may be willing to pay extra amounts for watershed conservation, they are constrained by legal and institutional gaps. The authority to increase water tariffs does not rest with the utility companies, but with the Water Services Regulatory Board (WASREB).

Financing of watershed conservation from WSTF and WRA presents a practical opportunity to sustain governance of water fund through basin water resource committees. WSTF and WRA have a mandate to incorporate supporting capacity building activities that aim at enabling WRUAs to develop and implement Catchment Management plans. The SCMPs take note of the connection between livelihoods and ecosystems in the management of water resources. Specifically, SCMPs set out to ensure equitable water allocation, reduce water pollution, promote sustainable land management practices, improve agricultural productivity, and protect natural wetlands and riparian reserves from human encroachment. However, due to capacity challenges, WRUAs faces serious difficulties in scaling up these initiatives. Despite their limited capacity to access and manage conservation funds, WRUAs have achieved

[210] Supra Note 172
[211] Ibid
[212] Ibid

community organization and restoration of publicly owned land. However, its ability to reverse land degradation trends on privately owned land is limited.

PRIVATE SECTOR-OPERATED MODEL

Under a private sector-operated model, a cooperate entity takes the lead in the management of the water fund. This is particularly so if the company understands and appreciates benefits of investing in watershed conservation to enhance business performance. This arrangement has been implemented in Brazil by water utility companies to reduce costs associated with water treatment.[213] Similarly, other companies in Brazil are currently pursuing an innovative arrangement of setting a water fund as a way of offsetting their water footprints.[214] This experiment can be an important source of raising revenue for long-term watershed conservation and management.

Private sector-operated water fund is potentially applicable in Kenya. Its effectiveness can be enhanced through partnerships with public sector actors. Currently, the involvement of corporate organizations in sustainability initiatives is adequate. Private sector entities are yet to reorient their business to address sustainability challenges internally linked to their value chain. However, a business case is required to motivate individual or collective private sector participation in landscape conservation approaches. While a private sector model for catchment conservation can be applied in Kenya, its effectiveness can be enhanced through partnerships with public sector agencies (*i.e.* a multi-stakeholder PPP model).

CONCLUSION AND RECOMMENDATIONS

In conclusion, we suggest the multi-stakeholder PPP model provides the most scalable avenue for coordinating and providing long-term resources for catchment protection and conservation. A diverse PPP model can harmonize private and public sector interests and combine entrepreneurial and government investments. Furthermore, policy, legal and institutional frameworks have been developed and established to regulate the process of engagement with private parties and implementation of project agreements. Through seeking to draw funding and technical support from a range of actors, including private companies and government agencies, as well as donors and NGOs, the multi-stakeholder PPP is effectively a hybrid approach which combines the strengths of a number of the other governance models mentioned above (*e.g.* combining government, private and CSO actors). It has a proven ability to mobilize not only financial resources, but also to draw on the technical capacity of diverse collaborative partners, thus overcoming some of the weaknesses with the other models mentioned above. For example, government financing of sustainability initiatives is often limited to narrow and smaller-budget projects, particularly in the context of Kenya and other less economically developed countries. Hence, government funding alone is unlikely to be sufficient to cover the scale of interventions proposed under the water fund, limiting the potential of a purely government-operated model. Similarly, private sector financing of sustainability projects may result in a relatively small budget which funds activities in the name of corporate social responsibility initiatives, which again are insufficient to match the scale of interventions proposed. Overall, PPP thus has the greatest potential to close the financing gap in environmental conservation and management, while ensuring the inclusion of governmental

[213] Supra Note 172
[214] Ibid

and non-governmental actors who can provide the required technical support to guide the fund's investment and intervention strategies.

The analysis of Kenya's policy, legal and institutional frameworks and a review of governance models are of practical relevance to the proposed MWF. The specific policy recommendations are provided below.

- **Capitalize on existing policy, legal and institutional frameworks on sustainable natural resources management.** Kenya has a strong legal and policy foundation to guide sustainable exploitation, utilization, management and conservation of the environment and natural resources. The Constitution of Kenya, *the Vision 2030*, the framework national environmental law, the national policy on environment, natural resources management policies and strategies, and relevant legislations, all create a sound basis for water fund mechanisms.

- **Tap into opportunities for multi-sectoral linkages and public-private partnerships.** Watershed management transcends across sectors such as water, agriculture, wildlife, environment, forestry, land use and energy. Further, the diverse range of actors in water sector creates opportunity for collaboration. An effective and efficient water fund mechanism requires the participation of key actors in watershed management. The PPP model can break stakeholders out of their silos and promote synergistic landscape-scale collaboration.

- **Capitalize on the funding gap for watershed management.** Currently there is no specific legislation on payment for ecosystem schemes that capitalize on and preserve regulating ecosystem services. The PPP model has a great potential to close the watershed management funding gap.

- **Explore innovative revenue streams to increase conservation finance**. Innovative pathways for resource mobilization are available both locally and internationally. Opportunities in global climate and concession financing mechanism have not been adequately explored. Additionally, local pathways such as Water Services Trust Fund enlarge the scope of collaboration with private investors over resource mobilization for catchment protection.

- **Focus on natural resources management policies that promote community participation in water and forest governance**. Water Resource Users Associations and Community Forest Associations offer avenue for scaling up conservation activities and livelihood systems that are environmentally friendly and suit local contexts.

- **Promote PPP models that optimize participation from civil society organizations**. A collaboration that brings together public sector entities, private sector and civil society organizations has the ability to benefit and support local communities. It will also build support for proposed conservation measures in the catchment.

12 PROPOSED STRUCTURE OF THE MWF

Based on our prior analysis of potential water fund stakeholders, funding and governance models, we propose that the MWF takes the form of a multistakeholder public private partnership. It will ideally receive payments and in-kind support from a range of contributors, including government, the private sector and international donors. A broad depiction of the proposed structure of the MWF is shown in Figure .

Drawing on the success of the UTNWF, it is recommended that the actual fund should be established as a charitable trust under Kenyan law. This is because the fund will be subject to fiscal regulations such as income tax should it be incorporated as a company, which would significantly reduce the amount of capital available to fund the proposed activities. One option would be to establish an endowment fund which would mitigate cash flow risks. The main capital is invested and the interest that is generated is used to finance catchment conservation activities, as well as any monitoring and evaluation activities. Partnerships with local NGOs, research organizations and various government bodies can also play an important role in providing advisory services and assisting with the implementation and monitoring of proposed water fund activities. The various components of the MWF are described further below, starting with a description of the proposed organizational structure of the Mombasa Water Fund Trust which will administer and manage the fund.

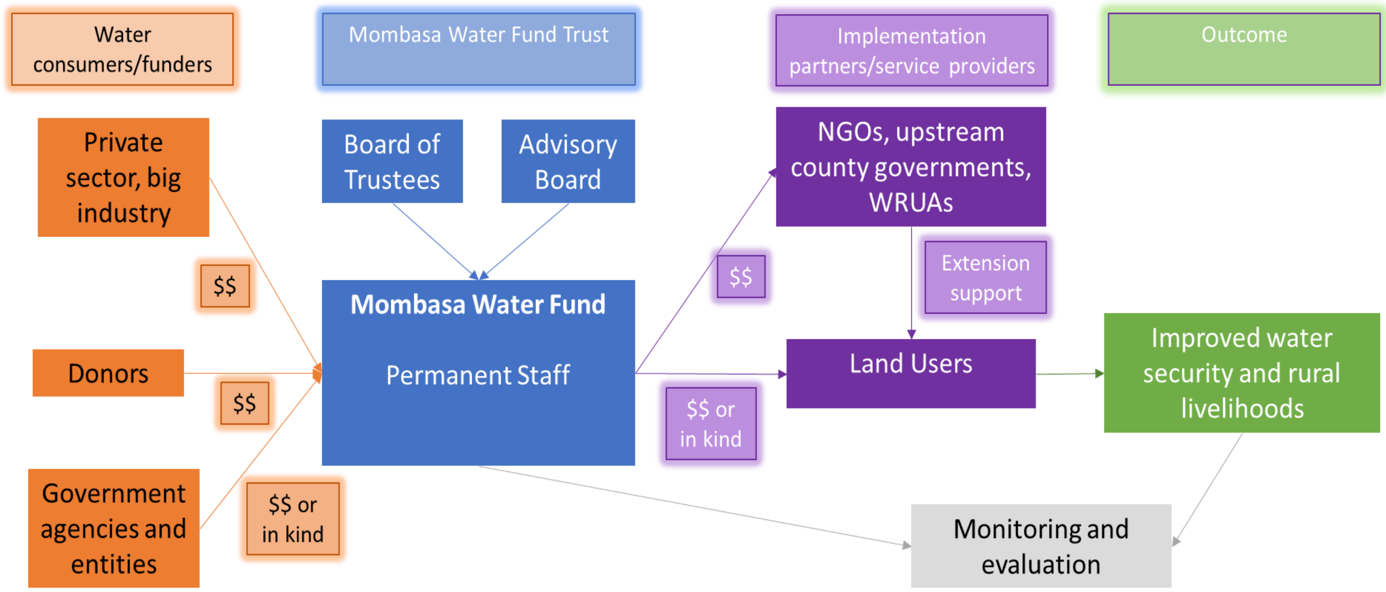


Figure 12-1. Broad schematic of the Mombasa Water Fund

ORGANIZATIONAL STRUCTURE OF THE MOMBASA WATER FUND TRUST

The proposed organizational structure for the Mombasa Water Fund Trust is shown in Figure . This represents the body which will be responsible for activities such as fundraising, financial and investment management and deciding how best to carry out the proposed activities. As is typical for a charitable trust, it will be headed by a Board of Trustees who will be held accountable for achieving the goals of the water fund. We also propose that the fund have an advisory board, potentially supported by one or more advisory committees. To minimize staffing costs, these roles will ideally be filled on a voluntary basis by stakeholders whose interests or mandates are aligned with the fund's goals. A relatively small number of permanent staff will be responsible for the daily management of the fund (indicated in dark blue in Figure). Further description of the role of these different structures within the MWF and potential stakeholders who could be included is provided below.

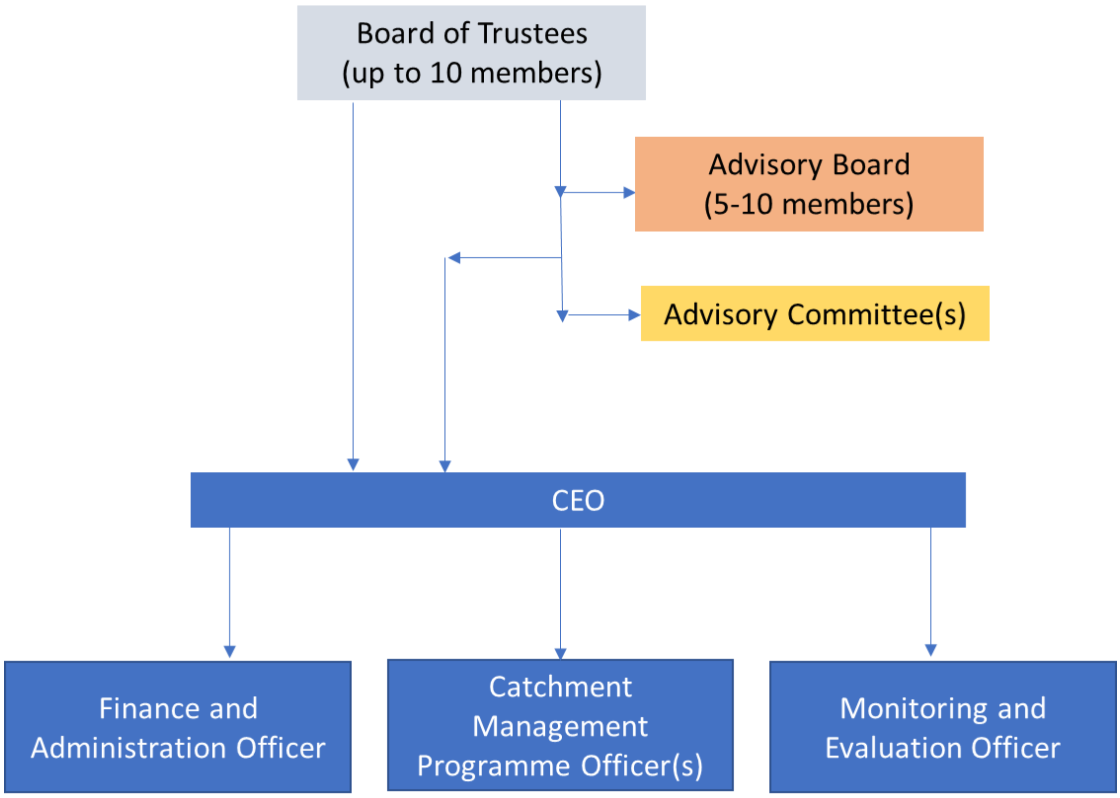


Figure 12-2. Potential organisation structure for the Mombasa Water Fund Charitable Trust (staff in dark blue comprise the full-time management staff)

Board of Trustees

At present, oversight and direction for the design of the MWF is provided by the steering committee, which includes representatives of a number of key stakeholders for the prospective fund. As incorporation of the fund as a charitable trust is finalized, the steering committee will be dissolved and replaced by a Board of Trustees (BoT). This Board should ideally comprise a relatively small number (around 10 or less) of representatives from key stakeholders in the fund. The BoT will be the body responsible for and held accountable for achieving the goals of the water fund. Its role will include providing policy direction and oversight, ensuring long-term sustainability and governance and management of the funding mechanisms in an efficient and appropriate manner which will sustain the proposed water fund activities. It is thus appropriate for organizations with the greatest financial stake in the water fund to be represented on the BoT. It is likely that a number of stakeholders currently sitting on the steering committee for the fund will end up on this Board.

Potential members of the BoT would include a representative from MOWASSCO and/or the County Government of Mombasa, since they have the greatest stake in securing future water supply from Mwache Dam. The bulk water authority (CWWDA or the nascent regional joint water authority which will take over from CWWDA) should also sit on the BoT, as their operations will be directly affected by sedimentation of the dam. At the national government level, a representative from WASREB could potentially be included on the BoT, particularly as they would have an interest in ensuring any funding derived from water user tariffs is put to good use. Depending on their level of commitment to the fund, a representative from MoWSI and/or the WRA might be included on the BoT. As the overall implementing agency for the fund, the Ministry in particular may have a sufficiently large stake in securing the future of the dam to warrant inclusion. One would also expect TNC to be a member of the BoT, along with representatives of any major donor funding partners which contribute to the fund. It could also include one or two representatives of the private sector, drawn from companies or organizations which have pledged to make a significant financial contribution to the fund. The President and Chairman of the BoT will ideally be well-known, influential and charismatic leaders with skills in multi-stakeholder coordination and proven ability in investment circles.

Advsiory Board

In addition to the BoT, we propose the establishment of an advisory board, tasked with providing over-arching managerial and technical support to help the fund achieve its aims. This will include providing direction on resource mobilization, fundraising, how the money generated by the fund should be used, oversight of monitoring and evaluation strategies as well as more technical advice on issues around the nature of conservation interventions implemented as part of the fund. Membership of the advisory board should accommodate the range of skillsets required for the over-arching operation and management of the fund, while seeking to ensure representation of key stakeholders. In addition to forming an advisory board, there may be a decision to form one or more advisory or technical committees of relevant experts to assist and feedback to the more high-level advisory board and permanent management staff of the water fund. For example, a technical committee could be created comprising experts on catchment management interventions. This could be beneficial for ensuring the advisory board does not get too large and cumbersome. In the case of the UTNWF for example, the decision was eventually made to form a counties advisory committee in addition to the Board of Management (roughly equivalent to the advisory board proposed here) (Kihara, pers. com). This committee includes representatives of all counties in the region along with representatives of state agencies which can provide valuable advisory services.

Part of the proposed role of the advisory board encompasses the mandates and interests of several existing institutions in the area. These organizations could thus provide in kind support to the fund through seconding staff to the advisory board, which in turn could help them fulfil their mandated duties. Representatives from the upstream County Governments of Kwale and Taita-Taveta could provide valuable advisory services around rural livelihoods and soil and water conservation interventions, as well as assisting with community outreach and liaison efforts. Experts from these counties could thus also play a role on any advisory committees formed to provide technical guidance to the fund. Inclusion of the upstream counties on the advisory board could also be important for gaining their buy-in, which will be crucial for the successful implementation of the proposed activities. The CDA could be another organization which warrants inclusion on the advisory board, as it is well placed to provide technical support around the proposed catchment rehabilitation interventions, given their ongoing experience in resource mobilization and implementation of similar interventions as part of the KWSCRP-II project. The same can be said for the WRA, which has the responsibility and relevant experience in catchment management throughout the country. Other national agencies such as KFS and KALRO can also provide useful technical and advisory support, as their expertise and interests encompass many of the interventions proposed under the water fund. Depending on their level of interest and commitment, such organisations could serve a role on the advisory board or on any technical committee(s) formed below it. Members of the advisory board tasked with financing, investments and fundraising could be sourced from private companies which have made a significant contribution to fund.

Permanent management staff

Following the example of the UTNWF, we propose that the MWF will include a small team of around five full-time managerial and administrative staff, tasked with managing the day-to-day operation of the fund. This body would be headed by a CEO or Executive Director, who would oversee the other permanent staff and be responsible for liaising with the BoT and advisory board. They would be supported by one or two programme officers in charge of implementing the various conservation interventions proposed as part of the fund. The staff should also include an officer in charge of monitoring and evaluation and an officer responsible for finance and administration. These staff would need to be provided with an office and vehicles to allow them to perform their duties.

The permanent water fund staff will liaise with implementation partners to carry out the fund's proposed activities. This will include making decisions about how to allocate available funding for the proposed activities and to whom, in line with the policy direction and rules set by the BoT and guidance given by the advisory board and technical/advisory committee(s). The permanent staff of the fund should thus be independent and not strongly affiliated with any of the potential implementing partners. If not, conflicts of interest would arise in decisions about which implementation partners to award grants to.

WATER CONSUMERS (FUNDERS)

It would be expected that the main beneficiaries of the MWF (*i.e.* water consumers) will provide meaningful support to the fund. As has been noted already, MOWASSCO and the County Government of Mombasa have some of the strongest incentives to support the fund, given the desperate need to secure and maintain improved water supplies to the city. The costs of sedimentation of the Mwache Dam will ultimately be borne by water users in Mombasa, in terms of worsening water shortages and/or potential tariff increases as water from Mwache Dam becomes more expensive due to sediment clearing and water treatment costs. It would also be in the interests of CWWDA or the new bulk water authority for the region to support the fund, potentially by integrating the costs of catchment conservation into their bulk water tariff (subject to WASREB approval), as reduced storage capacity from reservoir sedimentation will have a direct impact on their revenue from bulk water sales.

Although Kwale and Taita Taveta counties stand to gain little and no benefit respectively from water supplied by Mwache Dam, it was suggested that they may be encouraged to support the fund as a way of co-financing livelihood improvement and catchment management projects, in line with their constitutional mandates. This would be in addition to their role as providers of advisory services, as noted elsewhere. As the overall implementing agency for the Mwache Dam project, the MoWSI might also have an interest in contributing to the fund as a way of ensuring the long-term sustainability of the government's major infrastructural investment.

While most major private sector water users in the Mombasa area have resorted to using their own boreholes and other sources of water, there could be a significant appetite to revert to the use of municipal water as a cleaner, non-saline and more reliable source of water in the long-term. These major water users might thus consider contributing to the fund to ensure sustained future water supply for their businesses. Coca-Cola and Bamburi Cement have been identified as major water users who might be willing to support the fund in this regard. Further engagement with key private sector organizations such as the KCTA, KAM and KNCCI should be pursued to gain further private sector support for the fund.

DONORS AND OTHER POTENTIAL FUNDERS

As was the case with the UTNWF, TNC is likely to play a key role in providing seed capital for the MWF and lobbying for support from the various other potential funders identified here. Since TNC and AFD together identified the opportunity for the development of the MWF, AFD could play a similar role to TNC through providing seed capital and assisting with fundraising. AFD already has a well-established presence in water sphere in the region. For example, it has already provided a €120 million loan for the development of the water treatment works for Mwache Dam.

A number of donors and financing institutions which may have an interest in supporting the MWF were identified earlier in the report, though the list is by no means exhaustive. The World Bank has already been heavily involved in supporting catchment rehabilitation activities through the KWSCRP-II project, in partnership with CDA. Supporting the MWF could thus provide a means of upscaling the catchment rehabilitation work which they have funded to date. The International Fund for Agricultural Development (IFAW) was noted as a key potential funder given their extensive involvement in the Kenyan agricultural sector to data and their current interest in improving agricultural practices among smallholder farmers living in arid and semi-arid parts of Kenya (i.e. the majority of the Mwache Dam catchment). The Food and Agricultural Organization (FAO) similarly has interests in supporting smallholder farmers in Kenya and has a well-established field presence. The United States Agency for International Development (USAID) is another major donor presences in Kenya and supports projects in the water and sanitation sphere. Although it is a smaller donor agency, the Caterpillar Foundation as identified as a potential funder given its high stated interests in catchment conservation projects, as is evidenced by its support of the Upper-Tana Nairobi Water Fund. There are a range of other donor agencies active in Kenya which might also potentially fund the project, many of which are members of the Global Donor Platform for Rural Development, which may thus provide an entry point for further identification and engagement with potential donor funders.

POTENTIAL IMPLEMENTATION PARTNERS AND SERVICE PROVIDERS

The MWF can potentially deal directly with land users to implement the proposed activities or provide funding to implementation partners to carry out proposed activities. The relevant departments of the Kwale and Taita Taveta county governments are potential partners for implementing fund activities, as their constitutional mandate includes catchment conservation, livelihoods support and agricultural development. County government personnel from relevant departments should also have the expertise to apply proposed soil conservation measures successfully, tailored to the local context. Given the degree of overlap between the proposed activities of the MWF and mandate of counties to improve livelihoods, conduct catchment and natural resource management and support agricultural development, there could be potential for co-financing agreements between the MWF and the upstream county governments in implementing proposed activities as part of the fund. In this way, the water fund activities can be integrated with into county government plans and help them fulfil their constitutional mandates. It will be important to emphasize the potential for improved agricultural productivity and poverty reduction to encourage the support of the County Governments of Kwale and Taita Taveta for co-financing initiatives, given that they stand to gain little (Kwale) to no benefit (Taita Taveta) from any resulting positive impacts on water supply from Mwache Dam. Nevertheless, the willingness and/or means of these county governments to contribute to the fund financially may be limited, particularly if they feel the benefits of doing so are too small from their perspective. If so, the MWF may elect to award grants to the county governments to implement the proposed activities, without requiring co-financing commitments. Given that the county governments inevitably have many pressing developmental priorities, it would be important to ensure any such grants are used exclusively for carrying out the priority activities identified for combatting soil erosion.

Alternatively, or in addition to the upstream county governments, NGOs and CBOs with expertise in conducting soil erosion control and land restoration activities in the region could be important implementation partners and potential recipients of grants from the MWF. In this model, planned interventions under the MWF could be put out to tender and grants awarded to the best candidate organizations. In awarding grants to such organizations, the MWF should ensure the applicants are sufficiently qualified to carry out implementation of the planned activities, the organization's current legal and financial status, whether it has sufficient human capital and whether the proposed activities are sufficiently aligned with the organization's mission and work elsewhere. There is scope here for research institutions, larger NGOs and donor agencies to partner with and assist CBOs and smaller local NGOs with capacity building, training and other assistance to better enable them to apply for and implement grants provided through the MWF.

If sufficiently capacitated, WRUAs could represent useful community-level implementing agents for the proposed activities. Efforts have already been made to improve the capacity of WRUAs in the area, with around 14 now having produced sub-catchment management plans which include identification of key soil erosion issues and potential solutions (Bendera, pers. com). Grants given to WRUAs could thus be used to fund soil erosion control interventions on members' farmland and to support vegetation rehabilitation efforts in their particular sub-catchments. The county governments could serve a valuable advisory role in supporting the implementation activities of WRUAs under this model, as could other stakeholders with experience in implementing the proposed interventions (*e.g.* CDA, KALRO, KFS, KEFRI).

MONITORING AND EVALUATION

Monitoring and evaluation (M&E) will be important to ensure the MWF is achieving its desired outcomes, and to provide accountability to funding partners. This section provides an outline of the M&E plan for the MWF, including some of the key indicators it should focus on for demonstrating its impacts on water quality and quantity as well as benefits to rural livelihoods. These are summarized in Table 12-1.

There is a pressing need to increase the collection of flow and water quantity monitoring in the Mwache Dam catchment in particular. In this regard, the WRA is in the process of developing new water monitoring stations. Ideally, sufficient river monitoring stations should be established before significant land management interventions take place under the MWF, to improve understanding of the baseline situation in the absence of the fund. Given limited resources, water monitoring stations should be established primarily in sub-catchments within the lower half of the Mwache Dam catchment, since this is where degradation is generally most severe and where most of the planned water fund interventions will take place. Key parameters to be collected by these stations are turbidity, TSS and flow. Turbidity and TSS will be important for evaluating the impacts of the MWF interventions at reducing soil erosion and sedimentation, while flow data will be needed to evaluate impacts on water yield. A digital platform for the Chyulu Hills is currently in production, which will be useful for monitoring and evaluation of the PES scheme in the Mzima Springs recharge area.

It will also be important for the MWF to keep track of the areas and reach of the various proposed interventions. This can involve simple criteria such as the area of farmland under various soil erosion control measures and the number of farmers undertaking these, the area and number of households participating in PES schemes etc. As noted above, field and satellite-based monitoring will also be an essential component of the PES schemes themselves, to ensure compliance with the terms of payment. However, we also recommend periodic follow-up monitoring of other interventions, such as soil erosion control measures on farmland, to evaluate the extent to which such interventions are being maintained following their initial establishment. This will be important to ensure interventions do not become once-off events with no lasting impacts.

Table 12-1. Proposed outcomes indicators for monitoring and evaluation

Outcome	Indicator	Means of Verification
Reduction in sediment yields	Turbidity and TSS in water, sediment accumulation rates in check and main dams	Water quality and sediment monitoring data
Improved water quality	Nutrient and TSS concentrations	Water quality sampling data
Increase in water yields	Annual specific yield	Flow data from monitoring stations
Increased farm production	Crop production and income/ha	Farm production logs
Extent of implementation	Area of cultivated land with soil erosion control measures	Quarterly progress reports
	Area of degraded lands which have been restored	Quarterly progress reports
	Area of land actively participating in PES schemes	Quarterly progress reports
	Number of households with improved sanitation facilities	Quarterly progress reports
Reduced deforestation (particularly in Mzima Springs recharge area)	Annual area experiencing a decline in tree cover	Remote sensing (e.g. Global Forest Watch)
Improved vegetation cover	Collection of vegetation cover and biomass data	Field sampling and remote sensing

13 CONCLUSION

Land use practices in the Mwache Dam catchment area present a serious threat to the lifespan and potential water yield of the under-construction Mwache Dam, and water supply from the Mzima Springs is threatened by deforestation in its recharge area in and around the Chyulu Hills. A long-term commitment to investment in critical ecological infrastructure is needed to restore and protect the catchment areas of these important water source areas. Worldwide there is an increasing realization of the important role of catchment health in achieving water security. Healthy catchments regulate the timing, quantity and quality of stream flows, saving on grey infrastructure costs. Indeed, the degradation of ecological infrastructure leads to the need for more traditional grey infrastructure, or the need to fix or maintain existing grey infrastructure more regularly. This is particularly pertinent in the Mwache catchment given the construction of the Mwache Dam, the lifespan of which will be significantly curtailed if changes are not made soon to the way in which the catchment is managed.

The results demonstrate an economic basis for the establishment of a water fund. A US$31 million investment in restoration interventions in the Mwache Dam catchment is expected to return at least US$65 million in economic benefits over the 30-year timeframe. In other words, every US$1 invested by the Water Fund is expected to generate at least US$2.10 of benefits to stakeholders. This provides a compelling case for developers, such as The World Bank, to consider a long-term commitment to investing in ecological infrastructure to ensure the longevity of their grey infrastructure assets. Indeed, initial expenditure for effective intervention in the Mwache Dam catchment represents just 3% of the dam development cost. Therefore, the development of a water fund is timely. The construction of the dam is expected to take six to eight years to complete, providing enough time to restore already degraded areas and potentially halt any further degradation. Investment in the recommended activities now would mean that the restoration and conservation projects could be fully tested and implemented by the time the dam is operational.

In the Mzima Springs recharge area, a US$73 million investment in a Chyulu Hills Water PES scheme is expected to return about US$92 million in economic benefits over the 30-year timeframe, with an ROI of 1.3. The protection and restoration of the cloud forests and rangelands of the Mzima Springs recharge area is critical for ensuring the long-term supply of water to the Mombasa water supply system. Potential donors may be further motivated by maintaining the important biodiversity value of the area, the value of which (apart from tourism) is not fully included in this analysis.

Taken together, an investment of US$104 million in Water Fund interventions in the Mwache Dam catchment and the Mzima Springs recharge area is likely to return US$157 million in economic benefits, resulting in a net present value of US$53 million and a positive ROI of 1.5. Given the scarcity of data in some cases, and the difficulty in modeling the hydrology of the Mzima Springs, the calculation of benefits was conservative. Sensitivity analysis shows that costs could be increased, and benefits reduced further while still maintaining economic viability. While the Chyulu Hills Water PES Project will likely require further development to secure investment, ideally restoration and conservation interventions in both areas should be funded through the MWF to ensure improved water security for all users of the Mombasa water supply system. In addition to security of water supply, catchment restoration and conservation can bring wider benefits in terms of climate change resilience, job creation and community empowerment, and the restoration and protection of critical biodiversity.

14 REFERENCES

Abera, T.A., Heiskanen, J., Pellikka, P.K.E., Adhikari, H. & Maeda, E.E. (2020). Climatic impacts of bushland to cropland conversion in Eastern Africa. *Sci. Total Environ.* **717**, 137255.

Adams, B. (1986). *Tiwi Aquifer Study. Final Report*. British Geological Survey/Ministry of Water Development, Nariobi.

Addicott, E.T., Fenichel, E.P. & Kotchen, M.J. (2020). Even the Representative Agent Must Die: Using Demographics to Inform Long-Term Social Discount Rates. *J. Assoc. Environ. Resour. Econ.* **7**, 379–415.

AECOM. (2020). *Design and Implementation of a Pilot Water Payment for Ecosystem Services Scheme in the Chyulu Hills : Literature Review*. GNIplus.

Angima, S.D., Stott, D.E., O'Neill, M.K., Ong, C.K. & Weesies, G.A. (2003). Soil erosion prediction using RUSLE for central Kenyan highland conditions. *Agric. Ecosyst. Environ.* **97**, 295–308.

Aurecon. (2020). *Athi Basin Plan. Kenya Water Secuirty and Climate Resilience Project*. Nairobi, Kenya.

Van Den Bergh, J.C.J.M. & Botzen, W.J.W. (2014). A lower bound to the social cost of CO 2 emissions. *Nat. Clim. Chang.* **4**, 253–258.

Biamah, E.K., Gichuki, F.N. & Kaumbutho, P.G. (1993). Tillage methods and soil and water conservation in eastern Africa. *Soil Tillage Res.* **27**, 105–123.

Bimali, S. (2015). *Comparing Cost Data of Different Toilets in Peri Urban Areas of Developing Countries (Ethiopia, Kenya, Tanzania, Uganda and Nepal)*. Univeristy of Natural Resources and Applied Life Sciences, Vienna.

Black, J., Malesu, M., Oduor, A., Cherogony, K. & Nyabenge, M. (2012). *Rainwater harvesting inventory of Kenya*. *Icraf*.

Blume, S. (2009). *Cost Optimization of Single Door UDDTs in Kenya*. *Kenyan EcoSan Promot. Proj.* German Technical Cooperation Agency (GTZ).

Bond, W.J., Stevens, N., Midgley, G.F. & Lehmann, C.E.R. (2019). The Trouble with Trees: Afforestation Plans for Africa. *Trends Ecol. Evol.* **34**, 963–965.

Brauman, K.A., Benner, R., Benitez, S., Bremer, L. & Vigerstøl, K. (2019). Water Funds. In *Green Growth That Works*: 118–140.

van Breugel, P., Kindt, R., Lillesø, J.P.B., Bingham, M., Demissew, S., Dudley, C., Friis, I., Gachathi, F., Kalema, J., Mbago, F., Moshi, H.N., Mulumba, J., Namaganda, M., Ndangalasi, H.J., Ruffo, C.K., Védaste, M., Jamnadass, R. & Graudal, L. (2015). Potential Natural Vegetation Map of Eastern Africa (Burundi, Ethiopia, Kenya, Malawi, Rwanda, Tanzania, Uganda and Zambia). Version 2.0.

Chomba, S., Sinclair, F., Savadogo, P., Bourne, M., Lohbeck, M., Rother, D.C. & Scholes, R.J. (2020). Opportunities and Constraints for Using Farmer Managed Natural Regeneration for Land Restoration in Sub-Saharan Africa **3**.

Clarke, S. (2003). *An Evaluation of the Riparian Vegetation Index (RVI) in Kwazulu-Natal*.

Coast Development Authority. (2020a). *MWACHE DAM CATCHMENT MANAGEMENT PROJECT PROGRESS REPORT March 2020*. Mombasa, Kenya.

Coast Development Authority. (2020b). Mwache Catchment Management Project Progress Report September 2020.

Conservation International. (2018). Trends.Earth.

Cowie, A.L., Orr, B.J., Castillo Sanchez, V.M., Chasek, P., Crossman, N.D., Erlewein, A., Louwagie, G., Maron, M., Metternicht, G.I., Minelli, S., Tengberg, A.E., Walter, S. & Welton, S. (2018). Land in balance: The scientific conceptual framework for Land Degradation Neutrality. *Environ. Sci. Policy* **79**, 25–35.

Dallimer, M., Stringer, L.C., Orchard, S.E., Osano, P., Njoroge, G., Wen, C. & Gicheru, P. (2018). Who uses sustainable land management practices and what are the costs and benefits? Insights from Kenya. *L. Degrad. Dev.* **29**, 2822–2835.

Ellis-Jones, J. & Tengberg, A. (2000). The impact of indigenous soil and water conservation practices on soil productivity: examples from Kenya, Tanzania and Uganda. *L. Degrad. Dev.* **11**, 19–36.

Emerton, L. (2018). *Experiences and lessons learned in payments for ecosystem services (PES) in East Africa*. USAID.

Engel, S., Pagiola, S. & Wunder, S. (2008). Designing payments for environmental services in theory and practice: An overview of the issues. *Ecol. Econ.* **65**, 663–674.

ESA. (2017). Climate Change Initiative - Land Cover project 2017.

ESC. (2018a). *Options Study for Sustainable Management and Conservation of Mwache Catchment.*

ESC. (2018b). *Options study for sustainable management and conersvation of Mwache Catchment*. Nairobi, Kenya.

FAO. (2019). *Restoring Forest Landscapes Through Assisted Natural Regeneration (ANR)*. *Food Agric. Organ. United Nations*. Food and Agriuclture Organisation, Bangkok.

FAO. (2021). Conservation Agriculture [WWW Document]. URL http://www.fao.org/3/i7480e/i7480e.pdf

FAO & ITPS. (2018). *Global Soil Organic Carbon Map (GSOCmap) Technical Report*. Food and Agriculture Organization of the United Nations, Rome.

Fenta, A.A., Tsunekawa, A., Haregeweyn, N., Poesen, J., Tsubo, M., Borrelli, P., Panagos, P., Vanmaercke, M., Broeckx, J., Yasuda, H., Kawai, T. & Kurosaki, Y. (2020). Land susceptibility to water and wind erosion risks in the East Africa region. *Sci. Total Environ.* **703**, 135016.

Fischer, G., Nachtergaele, F., Prieler, S., van Velthuizen, H.T., Verelst, L. & Wiberg, D. (2012). Global Agro-ecological Zones Assessment for Agriculture (GAEZ 2008). *FAO, Rome, Italy IIASA, Laxenburg, Austria* 1–50.

Gathagu, J.N., Sang, J.K. & Maina, C.W. (2018). Modelling the impacts of structural conservation measures on sediment and water yield in Thika-Chania catchment, Kenya. *Int. Soil Water Conserv. Res.* **6**, 165–174.

Gilbert, M., Nicolas, G., Cinardi, G., Van Boeckel, T.P., Vanwambeke, S.O., Wint, G.R.W. & Robinson, T.P. (2018). Global distribution data for cattle, buffaloes, horses, sheep, goats, pigs, chickens and ducks in 2010. *Sci. Data* **5**.

Gilliam, J.W. (1994). Riparian Wetlands and Water Quality. *J. Environ. Qual.* **23**, 896–900.

Gleixner, S., Demissie, T. & Diro, G.T. (2020). Did ERA5 improve temperature and precipitation reanalysis over East Africa? *Atmosphere (Basel).* **11**.

GNIplus. (2021a). *Design and Implementation of a Water Payment for Ecosystem Services Scheme in the Chyulu Hills: Baseline Review*. London, UK, UK.

GNIplus. (2021b). Design and Implementation of a Water Payment for Ecosystem Services Scheme in the Chyulu Hills: Baseline Report.

Greener.Land. (2021). Greener.Land [WWW Document]. URL https://www.greener.land/

Hansen, M.C., Potapov, P.V., Moore, R., Hancher, M., Turubanova, S.A., Tyukavina, A., Thau, D., Stehman, S.V., Goetz, S.J., Loveland, T.R., Kommareddy, A., Egorov, A., Chini, L., Justice, C.O. & Townshend, J.R.G. (2013). High-Resolution Global maps of 21st-Century Forest Cover Change. *Science (80-.).* **342**, 846–850.

Hessel, R. & Tenge, A. (2008). A pragmatic approach to modelling soil and water conservation measures with a catchment scale erosion model. *Catena* **74**, 119–126.

Hood, W.G. & Naiman, R.J. (2000). Vulnerability of riparian zones to invasion by exotic vascular plants. *Plant Ecol.* **148**, 105–114.

Huber-Stearns, H.R., Bennett, D.E., Posner, S., Richards, R.C., Fair, J.H., Cousins, S.J.M. & Romulo, C.L. (2017). Social-ecological enabling conditions for payments for ecosystem services. *Ecol. Soc.* **22**.

IPCC. (2007). *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. *Intergov. Panel Clim. Chang.*

IUCN. (2021). Nature-based Solutions [WWW Document]. URL https://www.iucn.org/theme/nature-based-solutions

Jama, B., Elias, E. & Mogotsi, K. (2006). Role of agroforestry in improving food security and natural resource management in the drylands: a regional overview. *J. Drylands* **1**, 206–211.

Jones, A., Breuning-Madsen, H., Brossard, M., Dampha, A., Deckers, J., Dewitte, O., Gallali, T., Hallett, S., Jones, R., Kilasara, M., Le Roux, P., Micheli, E., Montanarella, L., Spaargaren, O., Thiombiano, L., Van Ranst, E., Yemefack, M. & Zougmoré, R. (2013). *Soil Atlas of Africa*. *Issn 1018-5593*.

Karuku, G.N. (2018). Soil and Water Conservation Measures and Challenges in Kenya; a Review. *Curr. Investig. Agric. Curr. Res.* **2**.

Kaumbutho, P. & Kienzle, J. (2007). *Conservation agriculture as practised in Kenya: two case studies*. African Conservation Tillage Network, Centre de Coopération Internationale de Recherche Agronomique pour le Développement, Food and Agriculture Organization, Nairobi.

King, J. & Pienaar, H. (2011). *Sustainable Use of South Africa's Inland Waters: A situation assessment of Resource Directed Measures 12 years after the 1998 National Water Act*. *WRC Rep.*

Kithiia, J. & Majambo, G. (2020). Motion but no speed: Colonial to post-colonial status of water and sanitation service provision in Mombasa city. *Cities* **107**.

KNBS. (2019a). *2019 Kenya Population and Housing Census Volume 1: Population by County and Sub-County*. *2019 Kenya Popul. Hous. Census*. Kenya National Bureau of Statistics, Nairobi.

KNBS. (2019b). *2019 Kenya population and housing census Volume 4: Distrbution of population by socio-economic characteristics*. *2019 Kenya Popul. Hous. census*. Kenya National Bureau of Statistics, Nairobi.

KNBS. (2020). *Kenya Economic Survey 2020*. Kenya National Bureau of Statistics (KNBS).

KWCA. (2016). *State of Wildlife Conservancies in Kenya Report*. Kenya Wildlife Conservancies Association, Nairobi.

KWSCRP. (2014). *Mwache Multipurpose Dam Project: Environmental and Social Impact Assessment*. Nairobi, Kenya.

KWSCRP. (2016). *Water Security and Climate Resilience in the Coastal Region, Kenya Environmental and Social Impact Assessment Study Report*.

Liniger, H., Mekdaschi Studer, R., Hauert, C. & Gurtner, M. (2011). *Sustainable Land Management in Practice: Guidelines and Best Practices for Sub-Saharan Africa*. *TerrAfrica, World Overv. Conserv. Approaches Technol.*

TerrAfrica, World Overview of Conservation Approaches and Technologies (WOCAT) and Food and Agriculture Organization of the United Nations (FAO).

Manga, M., Bartram, J. & Evans, B.E. (2020). Economic cost analysis of low-cost sanitation technology options in informal settlement areas (case study: Soweto, Johannesburg). *Int. J. Hyg. Environ. Health* **223**, 289–298.

Marenje WRUA. (2018). *Sub-Catchment Management Plan (SCMP): Marenje WRUA*.

Mati, B.M. (2006). *Overview of water and soil nutrient management under smallholder rain-fed agriculture in East Africa*.

Mbudyza, J., Ayuya, O.I. & Mshenga, P.M. (2017). Drivers of small scale farmers participation in agricultural land rental markets in Kenya. *African J. Rural Dev.* **2**, 511–522.

Mburu, B.K., Kung'u, J.B. & Muriuki, J.N. (2015). Climate change adaptation strategies by small-scale farmers in Yatta District, Kenya. *African J. Environ. Sci. Technol.* **9**, 712–722.

MEWNR. (2014). *Mwache Multipurpose Dam Project: Environmental and Social Impact Assessment (ESIA)*. Government of Kenya, Nairobi.

Monadjem, A. (2005). Association between avian communities and vegetation structure in a low-lying woodland-savanna ecosystem in Swaziland. *Ostrich* **76**, 45–55.

Monadjem, A. & Reside, A. (2008). The influence of riparian vegetation on the distribution and abundance of bats in an African savanna. *Acta Chiropterologica* **10**, 339–348.

Muhammed, N., Mwajuma, J.J., Budambula, V., Mang, G. & Nguru, J.F. (2018). Assessment of the Mzima – Baricho Distribution Lines for Drinking Water , Mombasa , Kenya. *IOSR J. Aplplied Chem.* **11**, 84–92.

Mulinge, W., Gicheru, P., Murithi, F., Maingi, P., Kihiu, E., Kirui, O.K. & Mirzabaev, A. (2016). Economics of Land Degradation and Improvement in Kenya. In *Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development*: 471–498. Cham: Springer International Publishing.

Mullegger, E. (2010). *Description and technical drawings: UDDTs Nakuru Kenya*. ESC Consulting Report.

Munialo, S., Dahlin, A.S., Onyango M., C., Oluoch-Kosura, W., Marstorp, H. & Öborn, I. (2020). Soil and management-related factors contributing to maize yield gaps in western Kenya. *Food Energy Secur.* **9**, 1–17.

Mwangi, J.N., Mboya, T.O. & Kihumba, J. (2001). Improved Maize Production in Central Kenya With Adoption of Soil and Water Conservation Measures. In *Seventh Eastern and Southern Africa Regional Maize Conference*: 299–300.

MWC&PC. (1994). *The Tiwi Aquifer - Groundwater Potential and the Development of the Source*. National Water Conservation and Pipeline Corporation.

MWI. (2017). *Water and Sanitation Development Programme: Environmental and Social Management Framework - ESMF*. Ministry of Water and Irrigation.

Naiman, R.J. & Décamps, H. (1997). The ecology of interfaces: Riparian zones. *Annu. Rev. Ecol. Syst.* **28**, 621–658.

Naiman, R.J., Décamps, H., McClain, M.E., Decamps, H., McClain, M.E., Décamps, H., McClain, M.E., Decamps, H. & McClain, M.E. (2005). *Riparia: Ecology, Conservation, and Management of Streamside Communities*. 1st edn. Burlington: Elsevier.

Narh, P., Lambini, C.K., Sabbi, M., Pham, V.D. & Nguyen, T.T. (2016). Land sector reforms in ghana, kenya and vietnam: A comparative analysis of their effectiveness. *Land* **5**, 1–17.

Ndegwa, G., Iiyama, M., Anhuf, D., Nehren, U. & Schlüter, S. (2017). Tree establishment and management on farms in the drylands: evaluation of different systems adopted by small-scale farmers in Mutomo District, Kenya. *Agrofor. Syst.* **91**, 1043–1055.

Ngaja, D. (2018). Community Conservancy model of conservation and income generation for local people [WWW Document]. *Panorama*. URL https://panorama.solutions/en/solution/community-conservancy-model-conservation-and-income-generation-local-people

Nippon Koei. (2018). *Design Review, Detailed Design and Construction Supervision for Mwache Multi-Purpose Dam. Chapter 3: Dams and Appurtenant Structures*. Nairobi, Kenya.

Nordhaus, W.D. (2017). Revisiting the social cost of carbon. *Proc. Natl. Acad. Sci. U. S. A.* **114**, 1518–1523.

Nyanchaga, E.N. (2016). *History of Water Supply and Governance in Kenya Lessons and*. Tampere, Finland: Tampere University Press.

Nyongoni WRUA. (2018). *Sub-Catchment Management Plan (SCMP): Nyongoni WRUA*. Mombasa, Kenya.

Nzau, J.M., Rogers, R., Shauri, H.S., Rieckmann, M. & Habel, J.C. (2018). Smallholder perceptions and communication gaps shape East African riparian ecosystems. *Biodivers. Conserv.* **27**, 3745–3757.

Ochieng, R., Masakha, E., Wegulo, F. & Koskei, E. (2013). Adaptation to Rainfall Variability by Smallholder Farmers in Kwale County African Journal of Education , Science and Technology , 2 (3): 228-241 : ISSN : 2309-9240. *African J. Educ. Sci. Technol.* **2**, 228–241.

Odera, J.A. (1997). Traditional Beliefs, Sacred Groves and Home Garden Technologies. In *Conservation and Utilization of Indigenous Medicinal Plants and Wild Relatives of Food Crops*: 43–48. Kinyua, A.M. & Kofi-Tsekpo, W.M. (Eds.). Nairobi, Kenya: UNESCO.

Ogutu, J.O., Piepho, H.P., Said, M.Y., Ojwang, G.O., Njino, L.W., Kifugo, S.C. & Wargute, P.W. (2016). Extreme wildlife declines and concurrent increase in livestock numbers in Kenya: What are the causes? *PLoS One* **11**, 1–46.

Oiro, S. & Comte, J.C. (2019). Drivers, patterns and velocity of saltwater intrusion in a stressed aquifer of the East African coast: Joint analysis of groundwater and geophysical data in southern Kenya. *J. African Earth Sci.* **149**, 334–347.

Okello, M. (2014). Economic Contribution, Challenges and Way Forward for Wildlife-Based Tourism Industry in Eastern African Countries. *J. Tour. Hosp.* **03**, 1–12.

Oshunsanya, S.O. & Aliku, O. (2017). Vetiver Grass: A Tool for Sustainable Agriculture. In *Grasses - Benefits, Diversities and Functional Roles*.

Panagos, P., Borrelli, P., Meusburger, K., Alewell, C., Lugato, E. & Montanarella, L. (2015a). Estimating the soil erosion cover-management factor at the European scale. *Land use policy* **48**, 38–50.

Panagos, P., Borrelli, P., Meusburger, K., Yu, B., Klik, A., Lim, K.J., Yang, J.E., Ni, J., Miao, C., Chattopadhyay, N., Sadeghi, S.H., Hazbavi, Z., Zabihi, M., Larionov, G.A., Krasnov, S.F., Gorobets, A. V., Levi, Y., Erpul, G., Birkel, C., Hoyos, N., Naipal, V., Oliveira, P.T.S., Bonilla, C.A., Meddi, M., Nel, W., Al Dashti, H., Boni, M., Diodato, N., Van Oost, K., Nearing, M. & Ballabio, C. (2017). Global rainfall erosivity assessment based on high-temporal resolution rainfall records. *Sci. Rep.* **7**.

Panagos, P., Borrelli, P., Meusburger, K., van der Zanden, E.H., Poesen, J. & Alewell, C. (2015b). Modelling the effect of support practices (P-factor) on the reduction of soil erosion by water at European scale. *Environ. Sci. Policy* **51**, 23–34.

Pekel, J.F., Cottam, A., Gorelick, N. & Belward, A.S. (2016). High-resolution mapping of global surface water and its long-term changes. *Nature* **540**, 418–422.

Pretty, J.N., Thompson, J. & Kiara, J.K. (1995). Agricultural regeneration in Kenya: The catchment approach to soil and water conservation. *Ambio* **24**, 7–15.

Price, R. (2017). *The contribution of wildlife to the economies of Sub Saharan Africa*. Department for International Development.

RCMRD. (2017). Kenya Crop Lands 2015 [WWW Document]. *RCMRD Geoportal*. URL http://geoportal.rcmrd.org/layers/servir%3Akenya_croplands_2015

Ricke, K., Drouet, L., Caldeira, K. & Tavoni, M. (2018). Country-level social cost of carbon. *Nat. Clim. Chang.* **8**, 895–900.

Rieck, C. & von Muench, E. (2011). *Technology review of urine diversion dehydration toilets (UDDTs): Design principles, urine and faeces management*. GIZ, Eschborn, Germany.

Riggio, J., Jacobson, A.P., Hijmans, R.J. & Caro, T. (2019). How effective are the protected areas of East Africa? *Glob. Ecol. Conserv.* **17**.

Roose, E. (1996). Land husbandry: Components and strategy. FAO Soils Bulletin 70.

RTI International. (2017). *Physiographic Survey of Mwache Watershed: Kenya Water Security and Climate Resilience Project – Phase* 2. Nairobi, Kenya.

Rural Focus Ltd. (2020). *Mombasa Water Fund – Pre-feasibility Study: Final Report (V3)*. The Nature Conservancy, Nairobi.

Sanghi, A., Damania, R., Manji, F. & Mogollon, M. (2017). *Standing out from the herd: An economic assessment of tourism in Kenya*. The World Bank.

Schmidt, R. (1992). Degradation of a forest in the Shimba Hills National Reserve, Kenya, as initiated by man and maintained by wildlife. *Trop. For. Transit.* 85–104.

Scholes, R.J., Bond, W.J. & Eckhardt, H.C. (2003). Vegetation dynamics in the Kruger ecosystem. In *The Kruger Experience: Ecology And Management Of Savanna Heterogeneity*: 243–262.

Shurie, M.M., Mwaniki, B. & Kameri-Mbote, P. (2017). *Water Permit Systems, Policy Reforms and Implications for Equity in Kenya*.

SoilGrids [WWW Document]. (2021). . URL https://soilgrids.org/

Soman, S., Beyeler, S., Kraft, S. & Winstanley, D. (2007). *Ecosystem Services from Riparian Areas: A Brief Summary of the Literature*. *Prep.* ….

de Sousa, L.M., Poggio, L., Dawes, G., Kempen, B. & van den Bosch, R. (2020). Computational Infrastructure of SoilGrids 2.0. *IFIP Adv. Inf. Commun. Technol.* **554 IFIP**, 24–31.

Spawn, S.A. & Gibbs, H.K. (2020). *Global Aboveground and Belowground Biomass Carbon Density Maps for the Year 2010*. ORNL DAAC, Oak Ridge, Tennessee, USA.

Tahal Group. (2013). *Consultancy Services for Water Supply Master Plan for Mombasa and other towns within Coast Province: Final Full Feasibility Study*. Coast Water Services Board.

Taner, M.Ü., Ray, P. & Brown, C. (2019). Incorporating Multidimensional Probabilistic Information Into Robustness-Based Water Systems Planning. *Water Resour. Res.* **55**, 3659–3679.

Tenge, A.J., De Graaff, J. & Hella, J.P. (2005). Financial efficiency of major soil and water conservation measures in West Usambara highlands, Tanzania. *Appl. Geogr.* **25**, 348–366.

Tenge, A.J., Sterk, G. & Okoba, B.O. (2011). Farmers' Preferences and Physical Effectiveness of Soil and Water Conservation Measures in the East African Highlands. *J. Soil Sci.* **2**, 84–100.
Thomas, D.B. (1997). *Soil and water conservation manual for Kenya*. Nairobi: Ministery of Agriculture : Soil and Water Conservation Branch.
Tol, R.S.J. (2008). The Social Cost of Carbon: Trends, Outliers and Catastrophes. *Econ. Open-Access, Open-Assessment E-Journal* **2**, 1.
Tol, R.S.J. (2011). The Social Cost of Carbon. *Annu. Rev. Resour. Econ.* **3**, 419–443.
Turpie, J., Letley, G., Chrystal, R., Corbella, S. & Stretch, D. (2017). *The value of Durban's natural capital and its role in Green Urban Development. Part 1: A spatial valuation of the natural and semi-natural open space areas in eThekwini Municipality*. World Bank Report; Washington, DC.
Turpie, J.K., Letley, G., Schmidt, K., Weiss, J., O'Farrell, P. & Jewitt, D. (2021). *Towards a method for accounting for ecosystem services and asset value: Pilot accounts for KwaZulu-Natal, South Africa, 2005-2011*. NCAVES project report: https://seea.un.org/content/knowledge-base.
Turpie, J.K., Letley, G., Schmidt, K., Weiss, J., O'Farrell, P.J. & Jewitt, D. (2020). *Towards a method for accounting for ecosystem services and asset value: Pilot accounts for KwaZulu-Natal , South Africa , 2005-2011. NCAVES project report*. Cape Town.
Turpie, J.K., Marais, C. & Blignaut, J.N. (2008). The working for water programme: Evolution of a payments for ecosystem services mechanism that addresses both poverty and ecosystem service delivery in South Africa. *Ecol. Econ.* **65**, 788–798.
Ulrich, L., Salian, P., Saul, C., Jüstrich, S. & Lüthi, C. (2016). *Assessing the Costs of on-site sanitation facilities*. eawag aquatic research and Sandec: Sanitation, Water and Soild Waste for Development, Dubendorf Switzerland.
UNEP-WCMC & IUCN. (2021). Protected Planet: The World Database on Protected Areas (WDPA) [Online] [WWW Document]. *Available at: www.protectedplanet.net*. URL http://protectedplanet.net/
Valle, E. & Yobesia, M.N. (2009). Economic Contribution of Tourism in Kenya. *Tour. Anal.* **14**, 1–14.
Wekesa, C., Mwalewa, S., Ongugo, P., Ndalilo, L. & ... (2017). *Smallholder farming systems in coastal Kenya: key trends and innovations for resilience. IIED Country Report*. International Institute for Environment and Development, London.
Wickama, J., Okoba, B. & Sterk, G. (2014). Effectiveness of sustainable land management measures in West Usambara highlands, Tanzania. *Catena* **118**, 91–102.
Wildlife Works Carbon. (2016). *Chyulu Hills REDD+ Project: Monitoring and implementation report*.
Wischmeier, W. & Smith, D. (1978). *Predicting rainfall erosion losses—a guide to conservation planning*.
World Bank. (2019). *The Role of Desalination in an Increasingly Water-Scarce World. Role Desalin. an Increasingly Water-Scarce World*. International Bank for Reconstruction and Development / The World Bank: Washington, DC.
WorldPop. (2020). Global High Resolution Population Denominators Project - Funded by The Bill and Melinda Gates Foundation.
Wunder, S., Börner, J., Ezzine-De-Blas, D., Feder, S. & Pagiola, S. (2020). Payments for environmental services: Past performance and pending potentials. *Annu. Rev. Resour. Econ.* **12**, 209–234.
Zamconsult. (2017). *Environmental and Social Impact Assessment Project Report for Baricho Lot 1: Augmentation of Baricho Well Field*. Ministry of Water & Irrigation, Coast Water Services Board.
Zhang, L., Cheng, L., Chiew, F. & Fu, B. (2018). Understanding the impacts of climate and landuse change on water yield. *Curr. Opin. Environ. Sustain.* **33**, 167–174.

15 APPENDIX 1: SELECTION PROCESS FOR DETERMINING SUITABLE SLM INTERVENTIONS

The suitability of SLM interventions was narrowed down based on several criteria (Table 15-1 to Table 15-4).

Table 15-1. Comprehensive typology of sustainable land management interventions. Degradation types addressed are based on Linger et al. (2011) with some additions. Effectiveness is ranked as follows: blank cells = insignificant, x = low, xx = moderate, xxx = high.

SLM intervention	Broad SLM intervention	Degradation addressed				
		Erosion	Chemical/ nutrient	Physical	Biological	Water
Agroforestry	Agricultural practices	xxx	xxx	x	xx	x
Farmer Managed Natural Regeneration (FMNR)		xx			xxx	xx
Conservation agriculture (CA)		xxx	xxx	xxx	x	xxx
Inorganic fertiliser application		x	xxx	xx		xx
Intercropping		x	xxx	xx		xx
Leguminous (nitrogen fixing) crop planting		x	xxx	xx		xx
Manuring and composting and Manure shed construction		x	xxx	xx		xx
Micro-catchments/zai-pits etc.		xx	x	xx	x	xxx
Seed/crop improvement		x	xxx	xx		xx
Orchard / timber plantation		x	xxx	xxx	xxx	
Community/private forest conservation or conservation easement	Conservation	xxx	xx	xx	xxx	xxx
Terracing/contour farming / *fanya juu* / stonewalling (stone bunds)	Cross-slope barriers	xxx		xx		xx
Vegetative/grass strips / trash lines		xxx		xx		xx
Active replanting/seeding / tree planting / Assisted natural regeneration (ANR)	Improved forest and riparian management	xxx	xx	xx	xxx	xx
Riparian rehabilitation (pegging, buffer strips, grass planting, bank stabilisation)		xxx	xx	xx	xxx	xx
Riparian protection		xxx	xx	xx	xxx	xx
Livestock management (including adjusting stocking densities / rotation / pastoralism / controlled grazing	Improved rangeland management	x	xxx	xx	xxx	xx
Conservancy model		xx		xx	xxx	x
Integrated crop-livestock management (ICLM)		x	xxx	xx	xxx	xx
Small irrigation management (surface, spate, rip, informal irrigation)	Irrigation management		xx	xxx		xxx
In situ rainwater harvesting and storage (household level) and small dams / ponds	Rainwater harvesting	x/xx	x	xx	x	xxx
Macro-catchments (check dams, channels, ditches etc.)		xx	x	xx	x	xxx
Non-NbS Interventions*						
Information dissemination	Education	N/A or Variable				
Water use efficiency improvement						
Upstream flow regulation reservoirs	Infrastructure					
Adjusting water tariffs	Policy					
Urban development regulation						

* Not elaborated on further

Table 15-2 Full list of interventions and their climate, slope and land cover suitability. Suitability scores are based on Linger et al. (2011) and supplemented with other references where necessary. Suitability scores: blank cells = insignificant, x = low, xx = moderate, xxx = high

SLM intervention	Broad SLM intervention	Climate suitability		Slope suitability				Land cover suitability				
		Semi-arid	Subhumid	0-5%	5-12%	12-40%	> 40%	Forest	Woodland and shrubland	Grass-land	Cultiv-ated land	Mixed (crop-livestock)
Agroforestry	Agricultural practices	xxx	xxx	xxx	xxx	xxx	xx	xx	xx	x	xxx	xx
Farmer Managed Natural Regeneration (FMNR)		xxx	xxx	xxx	xxx	xxx	xx	x	x	x	xxx	x
Conservation agriculture (CA)		xxx	xxx	xxx	xxx	xx	xx				xxx	xx
Crop residue mulching		xx	xxx	xxx	xxx	xx	x				xxx	xx
Inorganic fertiliser application		xxx	xxx	xxx	xxx					x	xxx	xx
Intercropping		xx	xxx									
Leguminous (nitrogen fixing) crop planting		xxx	xxx	xxx	xxx					x	xxx	xx
Manuring and composting and Manure shed construction		xxx	xxx	xxx	xxx					x	xxx	xx
Micro-catchments/zai-pits etc.		xxx	xx	xx	xxx	x	x		x	x	xxx	xx
Seed/crop improvement		xx	xxx	xxx	xxx	xxx	xxx				xxx	xx
Orchard / timber plantation		xx	xxx	xx	xxx	xxx	xx	xxx	xxx			xx
Terracing/contour farming / *fanya juu* / stonewalling (stone bunds)	Cross-slope barriers	xxx	xxx		xx	xxx	xxx		x	xx	xxx	
Vegetative/grass strips / trash lines		xxx	xxx		xx	xxx	xxx		x	xx	xxx	

SLM intervention	Broad SLM intervention	Climate suitability		Slope suitability				Land cover suitability				
		Semi-arid	Subhumid	0-5%	5-12%	12-40%	> 40%	Forest	Woodland and shrubland	Grass-land	Cultiv-ated land	Mixed (crop-livestock)
Community/private forest conservation or conservation easement	Conservation	xxx										
Active replanting/seeding / tree planting / Assisted natural regeneration (ANR)	Improved forest and riparian management	xx	xxx	xxx	xxx	xxx	xx	xxx	xxx	x	x	xx
Riparian rehabilitation (pegging, buffer strips, grass planting, bank stabilisation)		xxx	xxx	xxx	xxx	xx	xx	xx	xxx	xxx	xx	x
Riparian protection		xxx									x	x
Adjust stocking densities / rotation / pastoralism / controlled grazing	Improved rangeland management	xx	x	xxx	xxx	xx	x	x	x	xxx	x	xx
Conservancy model		xxx	xxx	xxx								x
Integrated crop-livestock management (ICLM)		x	xxx	xxx	xxx	xxx	xx	x	x	xxx	xxx	xx
Small irrigation management (surface, spate, rip, informal irrigation)	Irrigation management	xxx	xxx	xxx	xxx	xxx	x				xxx	xx
In situ rainwater harvesting and storage (household level) and small dams / ponds	Rainwater harvesting	xxx	xx	xx	xxx	x	x		x	x	xxx	xx
Macro-catchments (check dams, channels, ditches etc.)		xxx	xx	xx	xxx	x	x		x	x	xxx	xx

Table 15-3 List of selected SLM interventions list land tenure and farm-size suitability based on Linger et al. (2001). Suitability scores are based on Linger et al. (2011) and supplemented with other references where necessary. Suitability scores: blank cells = insignificant, x = low, xx = moderate, xxx = high

SLM intervention	Broad SLM intervention	Land tenure			Farm size		
		State	Communal	Private/indiv (depends on title)	Small	Medium	Large
Agroforestry	Agricultural practices	x	xx	xxx	xxx	xx	xx
Farmer Managed Natural Regeneration (FMNR)		x	xx	xxx	xxx	xx	xx
Conservation agriculture (CA)		xx	x	xxx	xxx	xxx	xxx
Crop residue mulching			xx	xxx	xxx	xxx	xxx
Inorganic fertiliser application			xx	xxx	xxx	xxx	xx
Intercropping		x	xxx	xxx	xx	xxx	xx
Leguminous (nitrogen fixing) crop planting			xx	xxx	xxx	xxx	xx
Manuring and composting and Manure shed construction			xx	xxx	xxx	xxx	xx
Micro-catchments/zai-pits etc.			x	xxx	xxx	xx	xx
Seed/crop improvement		xxx	xx	xx	xx	xxx	xxx
Orchard / timber plantation		xxx		x	x	xx	xxx
Terracing/contour farming / *fanya juu* / stonewalling (stone bunds)	Cross-slope barriers	xxx	xxx	xxx	xxx	xx	
Vegetative/grass strips / trash lines		xxx	xxx	xxx	xxx	xx	
Community/private forest conservation or conservation easement	Conservation	xxx	xx		xxx	xx	x
Active replanting/seeding / tree planting / Assisted natural regeneration (ANR)	Improved forest and riparian management	xxx	xx	xxx	xx	xxx	xx
Riparian rehabilitation (pegging, buffer strips, grass planting, bank stabilisation)		xxx	xx	xx	xxx	xx	x
Riparian protection		xxx	xx	x	xx	xx	xx
Livestock management (including adjusting stocking densities / rotation / pastoralism / controlled grazing	Improved rangeland management	xxx	xxx	xx	x	xx	xxx
Conservancy model		xxx	xx				xxx
Integrated crop-livestock management (ICLM)		xx	xxx	xx	xxx	xxx	xx
Small irrigation management (surface, spate, rip, informal irrigation)	Irrigation management	xx	xx	xxx	xxx	xx	
In situ rainwater harvesting and storage (household level) and small dams / ponds	Rainwater harvesting		x	xxx	xxx	xx	xx
Macro-catchments (check dams, channels, ditches etc.)			x	xxx	xxx	xx	xx

Table 15-4 List of selected SLM interventions and their required skills/knowledge, labour and costs, based on Linger et al. (2001). x = applicable, P = slightly positive, PP = positive, PPP = very positive, N = slightly negative, NN = negative, NNN = very negative.

SLM intervention	Broad SLM intervention	Skill and/or knowledge requirements			Labour requirements			Inputs and material costs**			Equipment costs**			Labour costs**			Cost-benefit ratio*	
		Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High	Short-term	Long-term
Agroforestry	Agricultural practices		x	x	Variable			x	x***	x***	x			x	x		P	PP
Farmer Managed Natural Regeneration (FMNR)			x		x			x			x						P	PP
Conservation agriculture (CA)****			x	x	x	x		x	x			x		x	x		P	PPP
Crop residue mulching		x	x		x	x		x			x			x				
Inorganic fertiliser application			x		x				x		x			x			PPP	PPP
Intercropping			x		x	x		x	x			x		x	x			
Leguminous (nitrogen fixing) crop planting			x		x			x			x			x			PP	PPP
Manuring and composting and Manure shed construction			x		x	x	x	x			x				x		PPP	PPP
Micro-catchments/zai-pits etc.		x				x		x			x			x	x		P	PP
Seed/crop improvement			x	x	x	x			x		x	x		x	x			
Orchard / timber plantation				x		x	x			x	v	v	v	v	v	v	N/N	V

SLM intervention	Broad SLM intervention	Skill and/or knowledge requirements			Labour requirements			Inputs and material costs**			Equipment costs**			Labour costs**			Cost-benefit ratio*	
		Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High	Short-term	Long-term
Terracing / contour farming / *fanya juu* / stonewalling (stone bunds)	Cross-slope barriers			x			x	x	x	x	x	x				x	N/NN	PP
Vegetative/grass strips / trash lines		x				x		x	x		x	x			x	x	N/P	PP
Community/private forest conservation or conservation easement	Conservation			x	Variable												N	PP*****
Active replanting/seeding / tree planting / Assisted natural regeneration (ANR)	Improved forest and riparian management		x			x		x			x	x		x	x			
Riparian rehabilitation (pegging, buffer strips, grass planting, bank stabilisation)			x	x		x	x	x	x	x							N	PP*****
Riparian protection		Variable															N	PP*****
Adjust stocking densities / rotation / pastoralism / controlled grazing	Improved rangeland management		x	x	Variable													
Conservancy model			x	x													N	PP*****

SLM intervention	Broad SLM intervention	Skill and/or knowledge requirements			Labour requirements			Inputs and material costs**			Equipment costs**			Labour costs**			Cost-benefit ratio*	
		Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High	Short-term	Long-term
Integrated crop-livestock management (ICLM)			x	x		x	x		x	x	x	x		x	x		P	PP/PPP
Small irrigation management (surface, spate, rip, informal irrigation)	Irrigation management			x		x	x				Variable						P/PP	PPP
In situ rainwater harvesting and storage (household level) and small dams / ponds	Rainwater harvesting		x	x			x	x			x				x	x	N	PPP
Macro-catchments (check dams, channels, ditches etc.)	Rainwater harvesting		x	x		x		x			x				x		NN	PP/PPP

* Blanks cells indicate unknown cost-benefit ratio
** Costs decrease after establishment
*** Inputs costs decrease significantly after establishment
**** Skills and costs are scale-dependent
***** Depending on long-term aim (biodiversity, livelihoods etc.)