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Local-level investments in natural water infrastructure:

Economic preferences, constraints and incentives for sustainable land management among farmers in the Upper Tana Basin, Kenya

BASQUE CENTRE FOR CLIMATE CHANGE
Klima Aldaketa Ikergai

Basque Centre for Climate Change - BC3, Spain

Project

This work by the Basque Centre for Climate Change (BC3) was undertaken as part of the Water Infrastructure Solutions from Ecosystem Services Underpinning Climate Resilient Policies and Programmes (WISE-UP to Climate) project. This project aims to demonstrate how natural infrastructure as a 'nature-based solution' contributes to climate change adaptation and sustainable development. The project has developed knowledge and options on the use of portfolios of built water infrastructure (e.g., dams, levees, irrigation channels) and natural infrastructure (e.g., wetlands, floodplains, watersheds) for poverty reduction, water-energy-food security, biodiversity conservation and climate resilience. The project is working in the Volta River Basin (Ghana, principally, and also Burkina Faso) as well as the Tana River Basin in Kenya.

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Disclaimer

Abstract

This paper focuses on the upper portion of the Tana River Basin: the mixed forest-agricultural landscape on the south-east slopes of the Aberdare Range and south-west slopes of Mount Kenya, which occupies the watershed for the tributaries that enter the Tana River upstream of the Seven Forks hydropower scheme. It investigates on-farm sustainable land management (SLM) as a local-level investment in managing upstream agroecosystems as water infrastructure.

To these ends, the paper addresses the question of: *what are the costs, benefits and risks to farmers of investing in SLM in the Upper Tana watershed in order to generate downstream water services?*

A review of evidence finds that that, although financial profitability may be a necessary condition for farmers in the Upper Tana Basin to choose to invest in a particular land management measure, by itself it is rarely sufficient. A broad array of other economic factors must be taken into account, which shape farmers' perceptions of the relative costs, benefits and risks of different SLM measures – and thus determine their willingness and ability to invest in SLM. Smallholders display a preference for SLM measures that can generate multiple and diverse cash and non-cash benefits, have low opportunity (not just absolute) costs relative to other demands and needs for resources, require only a small upfront investment, generate quick benefits, yield a steady and reliable stream of income and other outputs (especially during times of seasonal stress and shortage), and serve to reduce risk and minimise uncertainty. At the same time, external economic conditions and circumstances are found to serve as barriers which prevent farmers from being able to capture the potential gains from SLM, and thereby act as constraints to uptake. In particular, weak and exploitative labour markets, ineffective input markets, and unfavourable output prices drive a vicious downwards cycle of low agricultural productivity, poverty, and land degradation.

It is concluded that a better understanding of the role of risk and other economic factors that drive farmers' land use decisions can guide river basin managers in the design of more effective, equitable and sustainable instruments to encourage local-level investments in natural water infrastructure. Being able to identify and address these broader economic needs, preferences, constraints and opportunities can assist in ensuring that SLM systems are attractive, viable and sustainable from a farmer's viewpoint, as well as being effective, efficient and equitable from the perspective of integrated river basin management and towards the goal of delivering key water services.

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Acronyms

ACCESS	African Collaborative Centre for Earth System Sciences
BC3	Basque Centre for Climate Change
BMUB	German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
CIAT	International Center for Tropical Agriculture
CSA	Climate-smart agriculture
ICRAF	World Agroforestry Centre
IKI	International Climate Initiative
IUCN	International Union for Conservation of Nature
ISRIC	World Soil Information Centre
IWMI	International Water Management Institute
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KWTA	Kenya Water Towers Agency
MALF	Ministry of Agriculture Livestock and Fisheries
ODI	Overseas Development Institute
PRESA	Pro-Poor Rewards for Environmental Services in Africa
SIP	Sustainable intensification practices
SLM	Sustainable land management
TARDA	Tana and Athi Rivers Development Authority
WISE UP	Water Infrastructure Solutions from Ecosystem Services Underpinning Climate Resilient Policies and Programmes
WRMA	Water Resources Management Authority

INTRODUCTION: towards balanced water infrastructure portfolios

This report has been produced for the Basque Centre for Climate Change (BC3) as part of a consultancy carried out in support of the work package on "economic valuation and benefits" under the project "WISE UP to Climate – Water Infrastructure Solutions from Ecosystem Services Underpinning Climate Resilient Policies and Programmes". WISE UP aims to demonstrate the application of natural infrastructure as a nature-based solution for climate change adaptation and sustainable development in two River Basins in Africa: the Volta (Ghana-Burkina Faso) and Tana (Kenya). The intention is to generate new knowledge and innovative tools on optimising built infrastructure (e.g. dams, levees, irrigation channels) and natural infrastructure (e.g. forests, wetlands, floodplains, watersheds) and pilot their application by decision-makers and stakeholders engaged in climate change adaptation planning and river basin development, setting investment strategies for water infrastructure and dialogue over water resource management.

One of the major challenges in seeking to develop mixed portfolios of built and natural water infrastructure in a river basin planning and management context is to identify nature-based solutions which are simultaneously effective, efficient and equitable. Here, effectiveness is understood to refer to the ability of given infrastructure combinations to deliver the required water services. Efficiency involves optimising the allocation of investment funds and other resources to best achieve water service delivery and other desired outcomes. Equity relates to managing the trade-offs between different stakeholders' demands for land, resources and water, including balancing the needs of (upstream) ecosystem service providers and (downstream) beneficiaries. Sustainability requires the identification of viable, lasting solutions which can be maintained over the long-term.

Conventionally, the main focus of river basin planners (and of the decision-support information that is generated to guide them) is on the first two of these elements: on physical and financial aspects of water infrastructure investments. The overriding concern is to identify the best technologies and highest return investments. Recent years have also seen major advances in efforts to assess and value ecosystem services in order to make the case for investing in natural water infrastructure. There has however tended to be much less emphasis placed on equity and sustainability aspects. Yet, however much ecosystems are demonstrated to have the potential to deliver key water services, or river basin decision-makers are convinced of the wisdom of investing in natural water infrastructure facilities, this means little unless the groups who use, manage and impact on them are willing and able to support these initiatives. There is a need to identify interventions and instruments that make economic sense, and can be sustained, at the local level.

This paper investigates needs, niches and opportunities for managing upstream agroecosystems as an integral component of water infrastructure in the Tana River Basin. It is concerned with the ways in which risk and other factors affect farmers' land use choices and livelihood decisions, and thereby impact on the provision of water ecosystem services. Specifically, the paper seeks to investigate the costs, benefits and economic drivers that shape farmers' willingness and ability to invest in sustainable land management (SLM) practices (or, conversely, encourage or even force them into situations which result in land degradation and the loss of key ecosystem water services). The risks associated with ecosystem services, their livelihood impacts and the relevance of these risks for watershed management are particular topics of interest. The intention is to provide information which can be used in the design of instruments and interventions to encourage farm-level SLM investments in natural water infrastructure. The assumption is that a better understanding of the economic needs, preferences, circumstances and conditions that drive farmers' land use decisions can help in the design of more effective, balanced and better-targeted river basin management approaches and water infrastructure portfolios.

To these ends, the paper addresses the question of: *what are the costs, benefits and risks to farmers of investing in SLM in the Upper Tana watershed in order to generate downstream water services?* Using secondary sources, including data and information generated by WISE UP partners and others, it first of all reviews available evidence about the role of upstream agroecosystems in delivering water services in the Tana River Basin, and examines the economic implications for local farmers of managing the landscape as natural water infrastructure. A particular concern is to investigate whether profitability, alone, acts as a sufficient stimulus for the uptake of SLM. The paper then investigates the other economic and livelihood factors that serve to enable or (discourage) farmers to invest in SLM. It concludes by identifying how an understanding of farmers' economic preferences, constraints and incentives can assists in designing land-based interventions and instruments which will serve to leverage local-level investments in managing agroecosystems as natural water infrastructure.

POSING THE CHALLENGE: watershed degradation in the Tana River Basin

Land use, livelihoods and water infrastructure in the upper catchment

Stretching over a distance of some 900 km, the Tana River is Kenya's longest river (Figure 1). The entire river basin covers approximately 95,000 km^2 and is occupied by upwards of 6.5 million people (Baker et al. 2015, McCartney et al. in press). We are concerned with the uppermost portion of the basin: the mixed forest-agricultural landscape on the southeast slopes of the Aberdare Range and the south-western slopes of Mount Kenya (Figure 2). The Chania-Thika, Maragua and Gura-Sagana sub-watersheds, together with the rivers draining the south and south-eastern slopes of Mount Kenya which enter the Tana south of Masinga reservoir[1] are collectively termed the "Upper Tana Basin" (Knoop et al. 2012, TARDA 2017, Wilschut 2010). The Upper Tana is usually taken to refer to uplands areas above 1,300 metres, and occupies an area of something between 12,500 km^2 and 17,000 km^2, with a population variously estimated at something between 3-6 million people (Baker et al. 2015, Kamfor 2014, Njogu and Kitheka 2017, Said et al. 2007, TNC 2015).

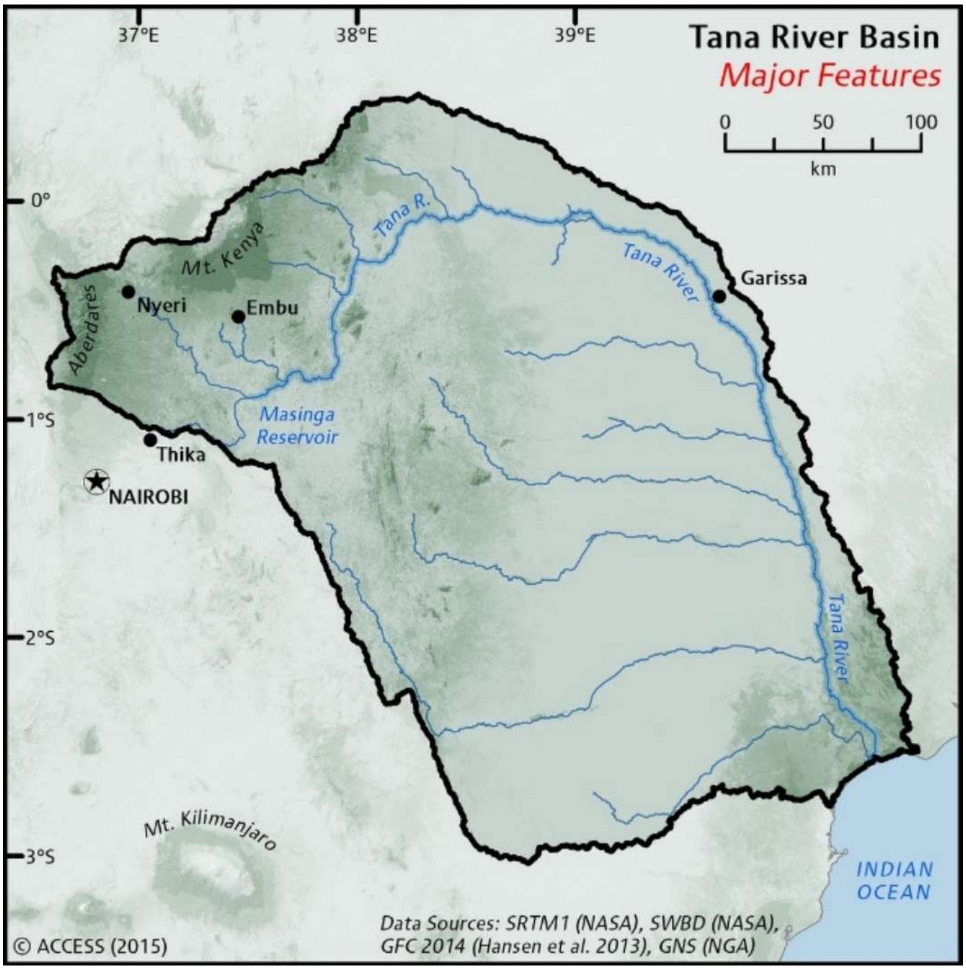
The watersheds of the Upper Basin contribute the vast majority of the Tana's flow, and directly feed a number of water infrastructure facilities which are of particularly critical importance for downstream users (Figure 3). The Chania and Thika rivers are the principal source of water for the Nairobi Metropolitan Area through Sasumua and Ndakaini dams (TNC 2015), as well as the proposed Northern Water Collector Tunnel which would transfer water from the Maragua river and its tributaries (Baker et al. 2015). Together with the Mathioya, Saba Saba, Gura and Sagana Rivers, the Maragua and Thika-Chania sub-watersheds feed into the western end of Masinga Reservoir, the first in the chain of dams which comprises the Seven Forks hydropower scheme[2] which generates around 40 per cent of the country's electricity output (McCartney et al. in press).

Above about 2,000 metres, the Upper Tana Basin is occupied by rocky mountains, high-altitude heathland, bamboo, grasslands and forest (Kizito et al. 2015, KWTA 2015). More than 20 per cent of the region is made up of mountainous areas, comprising glaciers and alpine habitats, surrounded at lower elevations by tropical montane forest (Said et al. 2007). Something between 85-90 per cent of the upper parts of the Aberdare and Mount Kenya water towers are covered by natural and plantation forest (KWTA 2015). A large proportion of forest, as well as high-altitude mountain areas, has been gazetted as protected areas, including various Forest Reserves as well as the Aberdare and Mount Kenya National Parks. Below the forest belt, the dominant land use is smallholder mixed agriculture. Smallholder farms exert a major influence over the local economy and, as we shall examine further below, the provision of downstream water services.

[1] Including the perennial Ena, Mutonga, Nyamindi and Thiba Rivers.

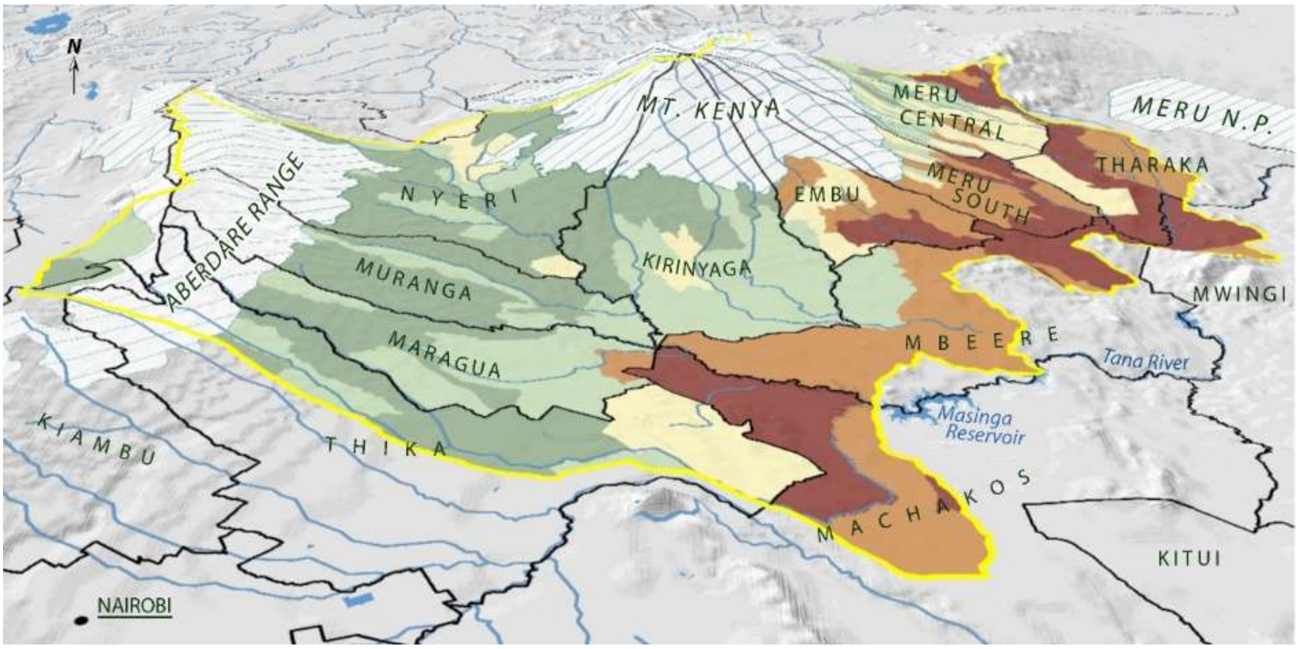
[2] Comprising Masinga, Gitaru, Kamburu, Kindaruma, Kiambeere and the planned Grand Falls and Mutonga power stations

Figure 1: The Tana River Basin



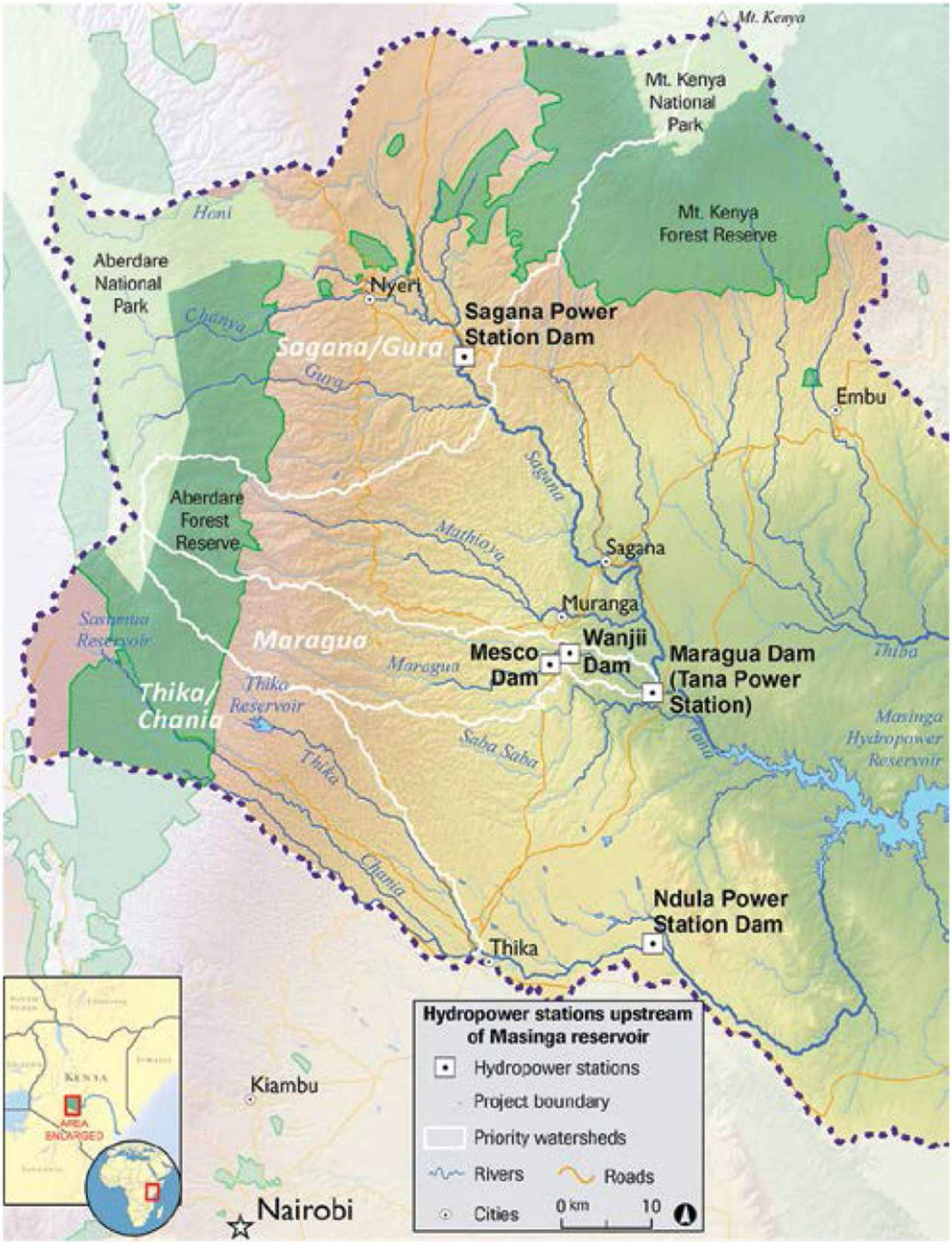
Source: African Collaborative Centre for Earth System Sciences (ACCESS), University of Nairobi/WISE-UP project.

Figure 2: Upper Tana Basin landforms and rivers



Source: Said et al. 2007 based on data from Central Bureau of Statistics (administrative boundaries); National Imagery and Mapping Agency of the United States (permanent rivers); Survey of Kenya, JICA and ILRI (250-meter Digital Elevation Model); Ministry of Water Development and JICA (subdrainage areas), FAO (landforms).

Figure 3: Major water supply and hydropower infrastructure in the Upper Tana Basin



Source: TNC 2015

The Upper Tana Basin is densely-populated, at an average of 250 persons/km^2, and the overall incidence of poverty is significant at 43 per cent (Said 2007). It should however be noted that the region contains a broad cross-section of very poor and less poor communities. The higher agricultural potential areas in the top section of the farming belt display some of Kenya's highest population densities (mostly between 300-600 persons/km^2) and lowest poverty rates. There are however also several very poor communities, mainly located in the less densely-settled, drier plains of Machakos, Mbeere, Tharaka, Igembe and Tigania, in the lower parts of the Upper Tana Basin towards the hydropower reservoirs. We are concerned mainly with the (relatively) more affluent, fertile highlands on the slopes of the Aberdare Range and Mount Kenya, comprising eastern parts of Muranga, southern Nyeri, northern Kirinyaga and Embu, and western Tharaka Nithi and Meru Counties.

Within the farming belt, land is intensively used: it is estimated that more than half of potential farmland in the upper basin is under some form of permanent cultivation (Baker et al. 2015, Hunink and Droogers 2015). This includes the tea-growing zones at the highest elevations of the foothills (mostly between 1,600-2,000 metres) and the coffee zone on somewhat lower slopes (1,300-1,600 metres). Rainfed farming is carried out over two seasons – the long rains (March to June) and short rains (October to December). Irrigation is also widely practiced across the upper watershed. Tea, coffee, pyrethrum and fruit trees such as mangoes, macadamia, avocado and other fruit and vegetables are important cash crops, while annual crops include maize, beans, Irish potatoes and sweet potatoes, which are typically grown for both home consumption and sale (Njogu and Kitheka 2017). A variety of livestock are kept including cattle, goats, sheep and poultry, and the upper slopes of the catchment constitute an important dairy production zone (Onduru et al. 2013).

Given the high population density, it is hardly surprising that land scarcity is acute in many parts of the fertile Upper Tana region, and farm sizes tend to be small at one hectare or less (Geertsma et al. 2009, Kamfor 2014, Leisher 2015, Pettinotti 2016, TNC 2015). Partly as a result of land scarcity but also in response to the wish to pursue a diversified production system and spread risk, farms are often split into several plots which are located in different parts of the landscape. The preferred configuration is for farms to occupy a narrow strip which stretches from hilltop to valley bottom (Pettinotti 2016). Hillside plots are planted mainly to rainfed tea, coffee, maize and beans, while small-scale irrigation often takes place on river banks and valley bottoms, primarily involving horticulture and floriculture (Hunink and Droogers 2015). While the majority of farmers carry out hillside farming, more fertile (and thus sought after) valley bottom plots tend to be difficult to access. For example, in Maragua, less than half of farmers cultivate valley bottom plots (Emerton and Gicheha 2017).

There is a well-developed road network in the region, facilitating access to numerous markets where food and cash crops are bought and sold (Baker et al. 2015). Although most parts of the Upper Tana are relatively well-integrated into the market economy, subsistence-level production remains an important component of people's livelihoods. A recent study in the Maragua sub-watershed for example found that a third of farmers farm for subsistence only (Emerton and Gicheha 2017), while a survey of farmers around the Kimakia river indicated that an average of 40 per cent of food crop production is kept for home consumption (Pettinotti 2016). However, while a large number of smallholders still grow food crops for subsistence, recent data show the growing importance of cash crops for household income. In upper parts of the watershed, cash crops occupy 50 per cent or more of farm area, a figure that is much higher than in lower parts of the watershed (Said et al. 2007).

Farming families are increasingly relying on cash income and the market economy for food security. Non-farm income tends to make an important contribution to household livelihoods, with up to three quarters of farm families also engaged in business, trade or employment (Emerton and Gicheha 2017) and most generating the majority of earnings from off-farm sources (Pettinotti 2016). Natural resources-based enterprises, including timber and fuelwood sales, charcoal burning, sand mining and brick-making, offer an additional source of income for many farmers, especially as a means of coping with seasonal shortages of food and income or to meet unforeseen or emergency cash needs (Kamfor 2014). Off-farm income sources, particularly casual labour and natural resource-based enterprises, tend to be particularly important for poorer, land-scarce households.

The effects of land degradation on downstream water supplies

This paper is concerned with the economic drivers of land use decisions, not with biophysical aspects of water ecosystem services. Various other authors describe the ways in which ecosystems in the Upper Tana Basin provide key hydrological services such as river flow regulation, flood mitigation, water storage, water purification, groundwater recharge and erosion control (see for example Baker et al. 2015, Bryant 2013, Dijkshoorn et al. 2011, Hunink et al. 2009, 2013, Kizito et al, 2014, KWTA 2015, McCartney et al. in press, Njogu and Kitheka 2017, Said 2007, UNEP 2012). As well as regulating the amount and timing or river flow, natural forests on the upper slopes of the Aberdares and Mount Kenya act to promote deposition of rainfall from clouds and fog. It is estimated that 5 per cent or more of rainfall in these areas is as a result of direct 'cloud harvesting' effects (Geertsma et al. 2009).

Ample evidence has been presented to suggest that these services are becoming increasingly compromised, as more and more land is given over to agriculture and as farming is becoming progressively more intensive in the fragile upper catchment (van Beukering and de Moel 2015). Much of the land in the foothills of the Aberdares and Mount Kenya that once was forest or a mosaic of forest and other natural habitats has now been cleared for settlement and agriculture (Said et al. 2007). It has become common for farmers to engage in crop production in forest remnants (Baker et al. 2015). While large tracts of the upper Tana have been gazetted as protected areas, a high proportion of the natural vegetation outside (or even along the edges of) these conservation zones has been modified, converted or otherwise degraded. A recent analysis of satellite images and aerial photographs across the Upper Basin shows that forest cover has reduced by more than 50 per cent since 1981, while the area under agriculture and settlements has more than doubled and cultivation on steep slopes and in areas of high erodibility has increased substantially (Njogu and Kitheka 2017).

In turn, these changes in land use and land management practices are linked to a wide variety of hydrological effects. The greater variation in the range of low and high flows as well as Increased sediment yields recorded in the upper catchment can be attributed at least in part to land conversion and the loss of natural vegetation (Brown et al. 1996, Hughes 1984), combined with poor agricultural land management practices that reduce land cover and cause high rates of soil erosion (Njogu and Kitheka 2017). with poorly-maintained farms and cultivation of marginal lands such as stream banks and steep slopes being cited as particular problems (Baker et al. 2015, Kitheka and Ongwenyi 2002, Wilschut 2010, WRMA 2008). Erosion has become particularly intense in smallholder farming areas, leading to increased runoff, higher and faster flows and greater sediment loads, especially in the rainy season (Knoop et al. 2012, TNC 2015). In total, it is now estimated that the sediment load in the Upper Tana varies from around 2,800 tonnes per day during dry season to about 24,300 tonnes per day during the rainy season (Kitheka et al. 2005) or between 1 and 8 million tonnes per year (Baker et al. 2015). At the same time, changes in land use and land management in the upper catchment are also reported to have impacted on dry season water availability (KWTA 2015).

The loss of these services has imposed high costs, losses and damages on downstream water users. It is reported that water supply costs now often increase by more than a third as sediment runoff fills and disrupts treatment equipment during the wet season (TNC 2015). With sedimentation rates between two and four times as high as the three million tonnes a year assumed during its design (Geertsma et al. 2009, TNC 2015), Masinga Dam had lost some 13.6 per cent of its design storage capacity to sedimentation by 2011 (Bunyasi et al. 2013). Meanwhile, the live volume of Kamburu reservoir has reduced by an estimated 15 per cent since 1983 (Hunink and Droogers 2015). The effects of watershed degradation are also manifested on-site, and severe reductions in soil fertility and farmland productivity have been recorded (Muriuki and Macharia 2011, van Beukering and de Moel 2015). The vast majority of farmers in the Upper Tana report some form of erosion on their land – between 60 and 80 per cent in the Chania/Thika and Sagana sub-catchments (Hunink and Droogers 2015, Kamfor 2014) and some 70 per cent in the upper Kimakia (Pettinotti 2016). Around two thirds of these farmers also suffer from declining soil fertility and moisture (Pettinotti 2016, TNC 2015).

Climate change is expected to exacerbate the effects of watershed degradation and to have a considerable (although as yet somewhat unpredictable) impact on water flows and sediments (Sood et al. 2017). The results of climate change analyses indicate higher rainfall, increases in both water yield and baseflow, and large escalations in the magnitude and frequency of floods into the future (McCartney et al. in press, Mueni 2016). While the resulting changes in water fluxes appear to be generally negative, impacts on sediment yields are less clear, with some projections showing an increase in loads and others indicating a decrease (Simons et al. 2017). A recent review of climate impacts on crop suitability also suggests that shifts in temperature and rainfall patterns will result in a progressively greater portion of the Chania/Thika watershed becoming suitable for maize and beans, especially areas that are currently planted to tea (Kizito et al. 2014). This suggests a potential future scenario that the lower half of the tea area is replaced by maize and beans and gives future cause for concern because of the effects on slope erosion and ground cover, and consequent implications for runoff and sedimentation.

MANAGING AGROECOSYSTEM WATER SERVICES: the gains from sustainable land management

SLM as a response to watershed degradation

Sustainable land management (SLM), often incorporating or combined with climate-smart agriculture (CSA) and sustainable intensification practices (SIP), is widely seen as a mechanism for restoring and managing the Upper Tana catchment, and thereby maintaining key downstream water services. It is worth noting that these three terms – SLM, CSA and SIP – are often used somewhat interchangeably, depending on the context in which they are being applied, the primary issues or goals they seek to address, and the interests or mandates of the individual or organisation that is referring to them. We take SLM as an overarching category, defined as “the adoption of land use systems that, through appropriate management practices, enables land users to maximize the economic and social benefits from the land while maintaining or enhancing the ecological support functions of the land resources” (FAO 2007). In turn, CSA overlays a concern with climate adaptation and mitigation as “agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes greenhouse gases (mitigation), and enhances achievement of national food security and development goals” (FAO 2010), while SIP is oriented towards practices which “aim to enhance the productivity and resilience of agricultural production systems while conserving the natural resource base” (Kassie et al. 2015, Pretty et al. 2011).

A large number of laws, policies, strategies, development plans and Institutional frameworks exist in Kenya which refer to – and to some extent attempt to operationalise – SLM as a means of addressing land degradation (Bati 2016). The Upper Tana Basin is considered a priority area for action. Thus, the promotion of SLM in the upper catchments of Mount Kenya and the Aberdare water towers features prominently in the Government of Kenya’s Strategic Investment Framework for Sustainable Land Management 2017-2027 (MENR 2016). It also forms a core part of the strategies, polices and plans of the public agencies that are mandated to manage and coordinate land and water resources in the Upper Tana Basin, including the Ministry of Agriculture Livestock and Fisheries (MALF), Water Resources Management Authority (WRMA), Tana and Athi Rivers Development Authority (TARDA) and Kenya Water Towers Agency (KWTA).

Several initiatives have also been implemented over recent years which explicitly aim to promote SLM among smallholder farmers in the Upper Tana Basin as a means of securing water services for downstream users. For example, the IFAD-funded Upper Tana Natural Resources Management Project has since 2012 been supporting on-farm interventions in key sub-catchments around the Aberdares and Mount Kenya. This includes the provision of grants for income-generating activities and soil and water conservation measures. Between 2007 and 2011 the Pro-Poor Rewards for Environmental Services in Africa (PRESA) project of the World Agroforestry Centre (ICRAF) investigated opportunities for developing payments for watershed services schemes around the Kapingazi River, a tributary of the Tana (see ICRAF 2011). These studies was carried out alongside the Green Water Credits project of the World Soil Information Centre (ISRIC) and Jomo Kenyatta University of Agriculture and Technology (JKUAT), which conducted research to explore the potential for direct payments to landholders in the Upper Tana Basin in return for land and water management activities (see Kauffman et al. 2014). Arising at least partially out of these initiatives, the Nairobi Water Fund, launched in 2015, uses payments from downstream water users to provide nearly 15,000 farmers in the Thika-Chania, Maragua and Sagana catchments with SLM training, resources and equipment (see TNC 2015). As these activities are only in the initial stages of being established, it is as yet too early to identify either their effectiveness in providing incentives for farmers to invest in SLM, or their impact on ecosystem status and water services in the Upper Tana Basin

The effectiveness and efficiency of SLM measures

Various authors underline the biophysical effectiveness of SLM as a means of securing water services in the Upper Tana catchment (Hunink et al. 2013, Knoop et al. 2012, Njogu and Kitheka 2017). An impressive range of quantified estimates of impact have been generated. For example, a recent modelling exercise demonstrated that on-farm soil conservation measures gives rise to significant positive effects across the Aberdares and Mount Kenya watersheds in terms of reduced erosion, decreased sedimentation, increased dry season surface water availability and improved groundwater recharge (Kauffman et al. 2014). Similarly, work carried out in the Sasumua catchment shows that contour farming and terraces can reduce surface runoff by 12 and 20 per cent respectively, and increase base flow by 6.5 and 12 per cent (Mwangi et al. 2015). A portfolio of riparian management, agroforestry, terracing, grass strips, reforestation and road mitigation measures has been linked to more than 50 per cent reductions in the sediment yields coming from agricultural land use classes in the Thika-Chania, Sagana and Maragua watersheds (Kauffman et al. 2015, Hunink and Droogers 2015), resulting in an 18 per cent decrease in the sediments reaching Masinga Dam and an increase of up to 15 per cent in annual water yields during the dry season (TNC 2015). Scaling up these results across the upper basin, it is suggested that tied ridges and terracing, alone, could reduce sediment inflow to Masinga reservoir by up to a million tons annually, while integrated packages of SLM measures could improve groundwater recharge and storage capacity by about 20 per cent (Hunink and Droogers 2010, Knoop et al. 2012).

Tracing the socioeconomic effects of these measures indicates substantial gains for a wide range of downstream water users. For example, a cost-benefit analysis of eleven commonly-applied SLM techniques in the Upper Tana Basin shows positive net benefits for rainfed farmers, irrigation schemes, domestic water supply utilities and hydropower schemes, ranging between tens and thousands of USD/ha/year (Droogers et al. 2011; Table 1). This translates into a substantial economic rate of return on public investments in SLM (Vogl et al. 2017). For example, calculations carried out to demonstrate the business case for the Nairobi Water Fund suggest a 30 year return of USD 21.5 million for downstream water users from a USD 10 million investment in SLM among smallholder farmers in the Sagana-Gura, Maragua, and Thika-Chania watersheds (Hunink and Droogers 2015, TNC 2015). Analysis of the effects of a package of 'green water management' SLM measures across the Upper Tana show similar results (Kauffman et al. 2014, Onduru and Muchena 2011). Preliminary estimates of the annual benefits derived are put at USD 51.9 million, compared to annual costs of USD 13.8 million (Droogers et al. 2011). This yields a ten-fold return on investment, half of which would arise from decreased siltation of hydropower reservoirs and the remainder from Improved water availability (ISRIC 2017).

Table 1: Cost-benefit analysis of selected SLM measures in the Upper Tana Basin (2011 USD/ha/year)

	On-site & off-site benefits	Construction costs	Maintenance costs	Average annual costs	Net benefit
Bench terraces	107	100	20	30	77
Conservation tillage	19	-	-	-	19
Contour tillage	93	-	-	-	93
Fanya juu terraces	97	200	20	40	57
Grass strips	57	50	20	25	32
Micro catchments	1,600	500	20	70	1,530
Mulching	55	-	-	-	55
Rangelands	6	50	-	5	1
Ridging	169	100	20	30	139
Riverine protection	200	100	20	30	170
Trash lines	37	50	20	25	12

Adapted from Droogers et al. 2011. Annualised values calculated over a 10-year period from first establishment, assuming a 20% adoption rate of appropriate SLM measures across farmland in Chania, Thika, Sagana, Thiba and Mutonga sub-catchments. Benefits calculated for rainfed farmers, irrigation schemes, domestic water supply utilities and hydropower schemes.

The positive effects claimed for SLM are not limited to downstream water users, but also accrue on-site, at the farm level. Figures from other parts of the Kenyan highlands cite yield increases of 50 per cent or more for practices such as terraces, ridges, grass strips and intercropping (see, for example, Mucheru-Muna et al. 2010, Mwangi et al. 2001, 2016, Okobe and Sterk 2006, Okeyo et al. 2014, Saiz et al. 2016). In the Upper Tana Basin, a wide variety of structural, vegetative and agronomic SLM measures have all been found to have strongly positive yield effects on both perennial and annual smallholder crops (Onduru and Muchena 2011).

Following on from this, a large number of studies have been carried out which demonstrate the profitability of SLM measures to smallholder farmers in the Upper Tana and elsewhere (MENR 2016). Several authors underline that SLM delivers substantial gains in crop revenue per hectare, due to avoided erosion, improved soil fertility and soil moisture (Droogers 2011, TNC 2015, Vogel and Wolny 2015). For example, in the Saba Saba sub-catchment, maize gross margins are shown to more than double when SLM techniques are applied (Atampugre 2011). Investment portfolios combining riparian management, agroforestry, terracing, grass strips and reforestation in the Thika-Chania, Sagana and Maragua watersheds show revenue increases of between USD 68/ha for smallholder mixed cropping, through USD 264 for coffee up to USD 479 for tea (Bryant 2015, Hunink and Droogers 2015, TNC 2015).

The financial efficiency of various SLM measures in selected sub-catchments of the Maragua, Chania, Mutonga and Saba Saba rivers has also been demonstrated for both perennial and annual crops. Most SLM techniques are found to give rise to positive gross margins, benefit-costs ratios of greater than one and IRRs which are substantially above prevailing market interest rates, as well as generating substantial value-added over a without SLM scenario (Atampugre 2011, Onduru and Muchena 2011; Table 2). Given that crop yields in many parts of the Upper Tana Basin are performing well below potential and in some instances are even declining or even negative (due in large part to severe land degradation and soil exhaustion), the application of SLM techniques is argued in some cases to make the difference between farms operating at a loss and turning a profit (Onduru et al. 2013).

Table 2: Returns to crop production with and without SLM in the Upper Tana Basin (2011 USD/ha/year)

	With SLM			Without SLM	SLM increment
	Benefit-cost ratio	Internal rate of return	Average annual benefit	Average annual benefit	Average annual benefit
Net benefits					
Perennial crops					
Microcatchment/banana	3.50	53%	1,287	578	710
Mulching/tea	1.10	31%	1,592	976	616
Zero tillage/coffee	1.00	30%	981	66	916
Structural measures with annual crops (maize and beans)					
Bench terraces	1.00	197%	2,914	-2,330	5,244
Fanya juu	1.10	202%	2,672	-1,446	4,118
Cut-off drains	1.30	195%	2,681	-1,022	3,703
Infiltration ditch	1.20	194%	2,650	-1,205	3,855
Stone lines	1.00	189%	1,138	172	966
Agronomic & vegetative measures with annual crops (maize and beans)					
Trash lines	1.10	471%	838	-24	862
Grass strips	8.00	566%	5,615	-37	5,652
Contour planting + tillage	0.50	N/A	322	-225	547
Contour ridging	1.20	N/A	375	-12	387
Gross benefits					
Perennial crops					
Terraces/tea	0.38	12%	690	397	293
Terraces/coffee	1.49	14%	550	238	312
Contour bunds/coffee	1.04	9%	427	229	197
Structural measures with annual crops (maize)					
Terraces	1.43	18%	243	54	188
Contour bunds	1.31	13%	133	54	78
Agronomic & vegetative measures with annual crops (maize)					
Grass strips	1.18	9%	84	54	29

Adapted from Atampugre 2011, Onduru and Muchena 2011. Annualised benefits calculated over a 15-year period from first establishment using a 10 percent discount rate for net benefits and 8.5% discount rate for gross benefits.

It should be noted that although the bulk of the literature paints an overwhelmingly positive picture of SLM profitability at the site level, this is not universally the case. It is not uncommon for SLM measures as they are applied in real-world situations (rather than the trial sites which inform many research papers) to post a net financial loss for participating farmers (Emerton 2016, Emerton and Gicheha 2017). In some instances, the main gains are for off-site or downstream beneficiaries not for upstream farmers. For example, modelling of the effects of various on-farm soil and water conservation measures in the Upper Tana found that although the provision of watershed protection services was great, there was a relatively low effect on the ecosystem service of food production, as indicated by the low gains (0–1 per cent) for crop transpiration that are directly related to yield – although there may be long-term beneficial effects (Kauffman et al. 2014).

How farmers are investing in SLM in the Upper Tana

Perhaps unsurprisingly, given the long history of soil and water conservation-oriented agricultural extension support and externally-funded projects, most farmers in the Upper Tana Basin are fairly knowledgeable about the range of SLM techniques open to them, are receptive to the idea of applying them on their farms, and are aware of the potential gains from doing so. For example, surveys carried out during the preparation of the Nairobi Water Fund found that more than 80 per cent of respondents in the Sagana-Gura, Maragua, and Thika-Chania watersheds could name at least two soil conservation measures, and around 95 per cent expressed an interest to participate in SLM activities (TNC 2015). A relatively wide range of structural, vegetative and agronomic SLM practices are widely-known and commonly-applied, including fanya juu and bench terraces, grass strips, contour planting, grain-legume intercropping, crop rotation, manure, bunds, retention ditches, cut-off drains and tree planting (Emerton and Gicheha 2017, Muriuki and Macharia 2011, Pettinotti 2016).

However, even though the majority of commonly-used SLM techniques have been demonstrated to be profitable (on paper at least) and are widely perceived by farmers to be beneficial, uptake is by no means universal. Measures are often applied only partially or are not sustained over any significant time period. Thus, although it is recorded that two thirds or more of farmers in the upper Tana have at least one soil conservation measure in place (Kamfor 2014, Onduru and Muchena 2011, Porras et al. 2007), the majority are only applying SLM across a quarter or less of their cropland (Hunink and Droogers 2015). Even when farmers state knowledge of a wide range of methods and are aware of their potential gains, this does not automatically translate into their actual uptake (Pettinotti 2016). Across the Upper Tana Basin, SLM measures tend to be poorly maintained, once established (Muriuki and Macharia 2011).

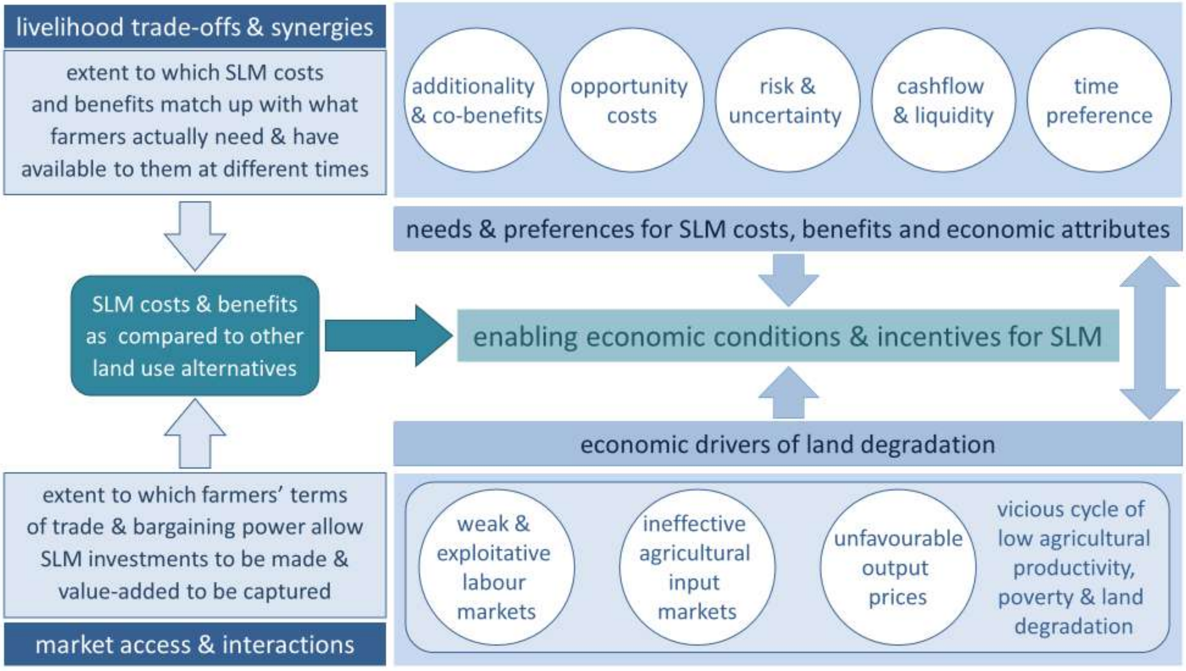
GOING BEYOND FINANCIAL PROFITABILITY: the economic drivers of land management decisions

Farmer perceptions of SLM costs, benefits and risks

On the one hand, it would seem to be self-evident that any new farming technique or technology should profitable. Farmers in the Upper Tana are for the most part unwilling (and often also unable) to adopt SLM practices if they do not yield a positive return on investment (Atampugre 2011, Geertsma et al. 2009). It is however clear that, although financial profitability may be a necessary condition for uptake, by itself it may not be sufficient to ensure that SLM is considered to be desirable, viable or feasible at the farm level. Several authors note that other economic and non-economic factors, too, need to be taken into account, which extend beyond monetary returns. In practice, a wide range of considerations inform the choice of whether to invest in SLM. (Emerton and Gicheha 2017). As well as non-market benefits and costs (Onduru and Muchena 2011, Porras 2007), these range from physical characteristics such as farm size, slope, rainfall and soil type (Muriuki and Macharia 2011, Tanui 2006) to institutional and legal conditions such as well-defined and secure tenure and property rights (Kabubo-Mariara 2015, Kassie et al. 2015, Wachira 2013). They also extend to motivations such as minimising uncertainty, avoiding risk, evening out fluctuations in the availability of food and cash, and strengthening resilience in the face of stresses and shocks (Emerton and Gicheha 2017). The concept of 'profitability' is far more nuanced than a simple formula based on balancing crop output, cash costs and earnings: the main elements that are taken into account when calculating the financial returns to SLM.

Below we consider the broader economic factors that shape farmers' perceptions of SLM profitability in the Upper Tana Basin. These respond to two main sets of drivers: livelihood trade-offs and synergies, and market access and interactions (Emerton 2016; Figure 4). The first relates to the extent to which SLM costs and benefits match up with what farmers actually need and have available to them at different times. They are shaped by the internal dynamics of the household economy, and influence the characteristics and attributes that farmers seek in SLM practices. The second concerns the extent to which farmers' bargaining power and terms of trade allow them to benefit from SLM investments. These drive farmers' performance and opportunities relative to their external economic environment, and determine whether they are in an economic position to be able to take up SLM, or find themselves in a situation where they have no option but to degrade the land and natural resource base in the course of their economic activities. Within these domains, nine characteristics emerge as particularly important determinants of farmers' willingness and ability to invest in SLM (or, conversely, as drivers of land degradation): additionality and co-benefits, opportunity costs, cashflow and liquidity, time preference, risk and uncertainty, weak and exploitative labour markets, ineffective input markets, and unfavourable output prices.

Figure 4: Economic drivers of farmers' SLM needs, preferences and decisions



Adapted from Emerton 2016.

Additionality and co-benefits

It would be over-simplistic to assume that farmers are motivated only by the prospect of enhanced crop yields or higher cash income. A single type of benefits is usually not enough to make SLM an economically appealing (or necessarily viable) option. The ability to 'stack' benefits is repeatedly cited as a key factor driving decisions to invest in SLM measures. It is typically the multiplicity of different outputs (not necessarily their absolute value) and their combined effect on different livelihood needs (not only their market earning potential or avoidance of cash losses) which together make SLM worthwhile.

What these additional benefits are and how highly each is valued (or required) will, of course, depend on a farmer's specific needs, aspirations and circumstances. Farmers in the Upper Tana cite a wide range of benefits and advantages that are decisive when weighing up the relative merits of different land management options and SLM techniques, of which income and crop yield are rarely the sole elements – and are frequently not perceived to be the most important ones (Emerton and Gicheha 2017). Certain common elements do however emerge. These include improvements in land condition such as soil structure, fertility and moisture as well as the generation of non-crop benefits such as improved water availability, a supply of livestock feed, or other outputs which can be sold for cash or used within the household (Onduru and Muchena 2011, Porras 2007). In the Maragua sub-catchment, six main categories of land management benefits and desired outcomes were identified as being the most sought-after: increased income, better and more reliable food supplies, higher crop yields, reduced soil erosion, more fertile soils and enhanced soil moisture (Emerton and Gicheha 2017). The majority of farmers identified the first three benefit categories as being essential, stating that they would not adopt SLM techniques unless they resulted in demonstrable gains in all of these areas.

Thus, although enhanced crop yields and higher cash earnings are important, by themselves they are not usually sufficient to persuade farmers to invest in SLM. Additional co-benefits are also required. For example, work in the Maragua sub-catchment suggests that manuring is a preferred SLM technique because of its long-term positive impacts on soil fertility and land productivity (and hence its knock-on effects on other aspects of farm production), and also because manure can be sold to earn income (Emerton and Gicheha 2017). In a similar vein, grass strips provide value-added to livelihoods because they not only generate soil and water conservation benefits, but also yield a supply of grass for sale or for feeding to cattle. Trees help to improve environmental conditions on-farm and also generate income. Terraces, as well as enhancing yields and improving soil moisture, also play a key role in risk reduction: when rainfall is low and crops fail elsewhere, it is usually possible to harvest at least a small amount of output in terraced fields.

Opportunity costs

Often it is not absolute cost that acts as the primary determinant of whether farmers are willing and able to afford to take up a particular SLM technique, but rather how different cost elements match up to farmers' endowments and with the alternative use of those resources elsewhere. Most farmers in the Upper Tana Basin pursue highly diversified livelihood strategies, combined of multiple elements, where factors or production are scarce and subject to many competing demands. There is a high opportunity cost to allocating land, labour, cash, farm inputs and other materials to SLM rather than to other productive ventures or income-generating activities (Emerton 2014). Even when sufficient labour, cash and other inputs are available, they may not be allocated to SLM as a first priority. This is particularly the case if the other activities that compete for these resources are believed to have the potential to yield higher returns, are deemed to be essential to household survival, or are considered to have greater importance in terms of the monetary or non-monetary payoffs they can generate.

As is the case with SLM benefits, the relative importance of different cost elements (and their opportunity costs) varies, depending on context. Cash and labour however seem to be associated with particularly high opportunity costs for farmers in the Upper Tana. In the Maragua sub-catchment, for example, unfeasibly high demands for cash and labour (relative to what is available to the farmer, rather than in absolute terms) were identified as among the greatest potential disadvantages and negative attributes influencing the choice of SLM practices (Emerton and Gicheha 2017). Labour is also cited in many other parts of the Upper Tana as a binding constraint for poorer families which often need to sell household labour off-farm in order to earn cash income (Atampugre 2011, Onduru and Muchena 2011, Onduru et al. 2013).

A range of other non-cash outlays and opportunity costs are also highlighted as barriers to the uptake of SLM, Several SLM techniques (for example terraces, stone lines and grass strips) reduce the land available on which to plant crops – a problem which can be particularly pressing in the land-scarce Upper Tana Basin (Emerton and Gicheha 2017), and may at the extreme even render production unprofitable (Porras et al. 2007). Many farmers simply cannot afford to take land out of production. The use of crop residues for mulching and green mature is another example of a SLM measure that often has a high opportunity cost, even though its cash costs are typically zero. Usually, mulching is only practiced on high-value crops, as crop residues are used mainly as a source of livestock fodder and are thus not normally reincorporated into the soil (Porras et al. 2007).

Cashflow and liquidity

The high opportunity cost of investing cash in SLM measures reflects its relative scarcity. Although farm livelihoods in the Upper Tana Basin are closely-integrated into the market economy and heavily dependent on bought inputs, most farmers have access to only limited sources of earnings, and farm production systems are still dominated by subsistence-level production. Furthermore, the times at which income is generated and cash is needed rarely coincide, as investigated further below. This means that considerations of cashflow and liquidity are important factors driving the decision to invest in SLM. Farmers frequently express the concern that processes of agricultural intensification have further increased their cash needs, while income-earning opportunities are becoming progressively scarcer. Finding sufficient amounts of cash, at the right times, to purchase the inputs that are required to carry out farming and to invest in SLM poses a binding constraint for many farm households (Emerton and Gicheha 2017).

Across most parts of the Upper Tana Basin, there is a high premium attached to cash earnings as compared to non-marketed output and products (and, conversely, a general aversion to purchased as compared to in-kind inputs). It is not just the overall output or income effects of SLM that are of interest, but the form in which they accrue (and, as we shall investigate further below, the time at which they accumulate). The preference is for SLM options that generate products and outputs that can be readily transformed into cash, so as to offset household expenditure needs (Porras et al. 2007). At the same time, SLM techniques that demand high levels of bought inputs are often beyond the reach of cash-poor farmers, even when their demonstrated profitability is high. In the Maragua sub-catchment, for example, the vast majority of farmers report that bought inputs almost always pose a significant challenge – and are often impossible – to access and afford in relation to SLM (Emerton and Gicheha 2017).

These considerations are important ones. The cash costs of establishing on-farm SLM techniques can be substantial, running to several hundred dollars per hectare for terraces, contour ridges and grass strips, and rising as high as USD 1,000 or more for agroforestry, reforestation and riparian protection (Atampugre 2011, Onduru and Muchena 2011, TNC 2015, Vogel and Wolny 2015). In many instances, investments in SLM may not be a feasible short-term option from a farmer's perspective, especially in the initial years where they yield negative returns (Atampugre 2011). Adding in annual maintenance costs of tens or even hundreds of USD per hectare and opportunity costs of lost production areas of anything up to USD 600 per hectare (Porras et al. 2007) increases the cash burden on farmers still further. In many cases, farmers are simply not able to afford these cash outlays (or cannot reallocate available cash from other, higher priority or more urgent uses) without additional credit or external assistance (Atampugre 2011, Onduru and Muchena 2011, Onduru et al. 2013).

Time preference

The issue of time preference is closely linked to farmers' cash constraints and needs for liquidity. It also reflects attitudes to risk and uncertainty (discussed further below). It is not only the absolute amount of benefits or costs generated by a SLM technique that is of importance, or even their timing over the course of the year in relation to needs and availability, but the rate at which they accrue. Many SLM techniques have high initial investment costs, while their benefits take a relatively long-time to accumulate. For example, it may be several years before tree products can be harvested or until land productivity is restored and is reflected in yield improvements. Farmers often cannot afford to wait a long time for this return. Current time preference has been found to be a particular feature for the poorest households, who are least able to wait for income, to bear short-term losses, or to finance the upfront cash investments that are required to start up new activities (Emerton 2014, 2016).

Several authors note that, despite positive overall financial indicators, many farmers in the Upper Tana Basin do not implement SLM measures because of the time lag between investment and returns: SLM is often not profitable in the short-term, or has a long payback period (Atampugre 2011, Onduru and Muchena 2011). In the Maragua sub-catchment, for example, the positive attributes and advantages which were deemed to be most important when choosing whether or not to take up a particular SLM technique related mainly to the timing of costs and benefits (Emerton and Gicheha 2017). Farmers expressed a strong preference for those SLM techniques which had proven ability to fill gaps in food and cash at critical times of the year, generate quick returns, have a lasting impact and only require a low upfront investment.

Different SLM techniques show a high degree of variability in the time before they show a positive return on investment, and this exerts a strong influence over rates of uptake. For example, the inclusion of grass or high value fodder crops planted to stabilise soil and water conservation structures reduces the payback period substantially, while incorporating organic and inorganic fertilisers can expedite productivity gains and thus shorten the time that farmers have to wait to recoup their initial investment (Onduru et al. 2013). Across the region, long-term SLM adoption has been found to be more likely when a technique is able to provide significant benefits in the first or second year (Barnard et al. 2015).

Risk and uncertainty

Various authors have concluded that, as in many other parts of the world, smallholder farmers in the Upper Tana Basin are generally risk averse as regards their response to the expected returns from the adoption of new technologies and techniques such as SLM (Kassie et al. 2008, Ogada et al. 2013, Wachira 2013). By a similar token, the need to manage (and where possible minimise or mitigate) risk and uncertainty is also found to exert an important influence on land management decisions. There is a general preference for SLM techniques that can help to minimise the risk of crop failure, and will serve even out the flow of food, income and other benefits over the course of the year to fill the gaps that arise at key stress points such as during the pre-harvest hungry season, at planting time when fertiliser and other inputs need to be procured, or when school fees are due. For example, in Maragua sub-catchment, farmers tend to favour SLM techniques that generate products or income at times when food and cash are otherwise scarce; this is the case even when their overall yield and income effects are low or, in extreme cases, negative (Emerton and Gicheha 2017, Emerton 2016). This degree of control and forward planning in an uncertain environment is emphasised as being highly desirable.

However, while SLM is a way of reducing the likelihood of disaster, it can also be a source of risk. Perceptions of risk often act as a constraint to uptake. SLM practices may be seen as involving risks, especially during the set up and establishment phase: for example the risk of crop yields being reduced (or failing altogether), or of taking away cash and other resources from alternative productive uses. Reluctance to engage in potentially risky activities is often compounded by weak knowledge (and thus high levels of uncertainty) about the eventual effects or efficacy of some SLM practices, especially those which are newly introduced from outside, or which farmers are not already familiar with (Emerton 2016, Emerton and Gicheha 2017). Even when SLM gives rise to higher farm profits over the long-term, the high risks and uncertainty about future gains that are associated with the early stages of establishing new farm management practices can act as a barrier to investment – especially for poorer and more vulnerable farmers (Barnard et al. 2015, Hobbs 2017). It is often the case that people are less likely to invest in SLM (or more likely to abandon SLM practices) when they face a downturn in economic conditions, or are experiencing uncertainty about other aspects of their livelihoods. Several authors have for example noted that the application of SLM techniques in the Upper Tana Basin is highly sensitive to farm profitability: when crop prices fall (especially for tea and coffee), SLM tends to be abandoned (Muriuki and Macharia 2011, Tanui 2006).

Market access and interactions

As mentioned above, most farmers in the Upper Tana Basin are closely integrated into the market economy. Crop sales underpin household income, while off-farm earnings, particularly from casual agricultural labour, also offer an important source of cash (Kamfor 2014, Leisher 2015, Pettinotti 2016). The majority of farmers also rely on purchased seed, fertilisers and other farm inputs – a dependence that is steadily growing, as farmland becomes progressively exhausted and soil fertility continues to decline (Emerton and Gicheha 2017, Kamfor 2014, TNC 2015). Yet many – or even most – farmers are often unable to benefit fully from these opportunities, and have only weak bargaining power to negotiate any improvement in the terms of trade they face (Emerton and Gicheha 2017). This is argued to perpetuate the low farm returns and chronic shortages of food and cash that prevent or discourage farmers from taking up SLM or distort incentives away from adopting SLM, and drive unsustainable land management practices in the first place (Barbier 2000, Emerton 2016). Several authors argue that any effort to persuade farmers to engage in SLM, without finding concrete solutions to the problems they face in terms of poverty and market access, is futile (Giordano 2003).

Market conditions in the Upper Tana Basin can make it hard for farmers to break out of the so-called "vicious economic cycle" of low agricultural productivity, poverty, and land degradation and to instead enter into "virtuous cycles" or "upward spirals" of SLM, improved livelihoods and enhanced economic status (Emerton and Gicheha 2017, Geertsma et al. 2009, Pender et al. 2006, Tanui 2006). They also mean that there is often also a marked divergence between farmers' needs and preferences for SLM and actual uptake patterns. Even when a land management technique may be perceived to be of great interest and high potential benefit, it may not be possible for farmers to obtain the extra inputs that are required to implement it or to access the market opportunities that would make it profitable over the *status quo* or as compared to an inferior (but easier to implement) option (Emerton and Gicheha 2017). In many cases farmers' choice of SLM techniques is a second-best one. Households are not necessarily able to choose the land management options that they consider to be most effective for SLM or most desirable in economic terms, but undertake those that they are able to accomplish, given their economic circumstances and resource endowments.

The ability to sell crops for a fair price exerts an important influence on farm profitability, and thus on farmers' willingness and capacity to continue to enter into and maintain SLM investments (Tanui 2006). Most farmers in the Upper Tana are price-takers, relying on external middlemen and traders that come into the area to buy farm produce for onward sale elsewhere (Kamfor 2014). In many cases, the prices offered for farm produce are extremely low, and are also uncertain and highly variable over the course of the year (Kabubo-Mariara 2015, Onduru et al. 2013). In some instances they are not even sufficient to cover basic costs of production (Emerton and Gicheha 2017). Cash shortages mean that many farmers are forced to sell their crops immediately after harvest, when prices are lowest. Not only does this undermine earnings, but it also leaves households in a position where they must purchase food later on in the year, at a much higher price (Geertsma et al. 2009). The lack of processing facilities in the locality (aside from tea and coffee factories) also means that the potential for value-added is low. Crops tend to be sold in small quantities, mainly in their raw form, attracting low price premiums (Kamfor 2014).

As in other parts of Kenya, farmers in the Upper Tana Basin cite the high price of inputs as a binding constraint to agricultural productivity and farm profitability, leading to unsustainable intensification and the expansion of farms into more and more marginal areas (Kabubo-Mariara 2015, Kamfor 2014). However, even when cash is available, it may not be possible for farmers to access appropriate, quality inputs – the improved seeds, fertilisers and pesticides that are available in local shops are often sold out, of poor quality or even adulterated (Emerton and Gicheha 2017).

Many farmers in the Upper Tana Basin rely on the sale of their own or other family labour as a main source of cash income, most commonly through working on other people's farms or as casual labourers in nearby towns and trading centres (Kamfor 2014, Pettinotti 2016, Tanui 2006). This tends to be particularly important at certain times of the year – for example when cash is required to buy inputs at planting time, or at the end of the growing season when food supplies have become short (Emerton 2016). The times of peak labour sales thus often coincide with the times when labour is needed most on-farm, thereby impacting on productivity (Emerton and Gicheha 2017). It leads to a labour dilemma: In order to satisfy immediate needs for cash and food, as well as to generate the income that is required to buy production materials and inputs (including for SLM), farmers have few alternatives but to sell their labour at the very time when they should be preparing, planting and weeding their own fields (Emerton 2016). It has already been noted elsewhere literature that this has serious consequences for both crop output and land degradation, leading to a progressively worsening cycle of intensifying cash needs, rising food deficits, diversion of household labour to casual wage earning, progressive erosion of livelihoods and unsustainable farming practices (Geertsma et al. 2009, Pender et al. 2006, Tanui 2006). These effects are exacerbated by the weak and exploitative labour markets that persist in the Upper Tana, which offer low wage rates, long hours and often delayed payments (Emerton and Gicheha 2017).

CONCLUSIONS: leveraging on-farm investments in natural water infrastructure

This paper began by posing the question: what are the costs, benefits and risks to farmers of investing in SLM in the Upper Tana watershed in order to generate downstream water services? The aim was to provide a better understanding of the economic needs, preferences, conditions and circumstances that drive farmers' land use decisions in the Upper Tana Basin, so as to provide information that would have relevance to the design of more effective, sustainable and better-targeted interventions to encourage local-level investments in agroecosystems as natural water infrastructure.

A key finding is that although financial profitability may be a necessary condition for farmers to choose to invest in a particular land management measure, by itself it is not sufficient to ensure that SLM is considered to be either desirable or feasible at the farm level. At best, it provides only a weak predictor of what farmers themselves perceive to be the positive and negative economic attributes associated with different land management choices, and whether (and to what extent) they will be willing and able to adopt SLM. The economic drivers of farmers' land use decisions in the Upper Tana Basin extend far beyond efforts to maximise short-term income and production or to minimise cash expenditures. These findings echo those of studies carried out in other parts of Kenya and sub-Saharan more generally (see, for example, Emerton 2014 and 2016, Gebremedhin 2004, Kassie et al. 2015, Pender et al. 2006, Tanui et al. 2013).

A review of experiences from the Upper Tana Basin points to a range of other factors that serve to enable (or discourage) farmers to invest in SLM. Farmers highlight a broad array of economic attributes and characteristics which they seek (or look to avoid) when they make land management choices, and which indicate the relative desirability, viability and sustainability of different SLM options to them. Smallholder farmers in the Upper Tana Basin display a preference for SLM measures that can generate multiple and diverse benefits, have low opportunity (rather than necessarily absolute) costs relative to other demands and needs for resources, require small upfront costs, generate quick benefits, yield a steady stream of income and other outputs (especially during times of critical stress and shortage), and serve to reduce risk and minimise uncertainty.

At the same time, farmers' external economic conditions and circumstances were found to serve as barriers which prevent them from being able to capture the potential gains from SLM, and thus act as a constraints to uptake. Foremost were poorly-functioning (and often exploitative) output, input and labour markets, in which farmers had only weak bargaining power to negotiate any improvement in the terms of trade they face. Market conditions make it hard for farmers in the Upper Tana to break out of the so-called "vicious economic cycle" of low agricultural productivity, poverty, and land degradation.

Being able to identify and address these broader economic needs, preferences, constraints and opportunities can assist in ensuring that SLM systems are attractive, viable and sustainable from a farmer's viewpoint, as well as being effective, efficient and equitable from the perspective of integrated river basin management and towards the goal of delivering key water services. To these ends, the paper yields four main conclusions for river-basin planners and policy-makers concerning the design and implementation of interventions to leverage local-level investments in agroecosystems as natural water infrastructure:

a) Upstream agroecosystems are a key component of the water supply chain in the Tana Basin. As such, efforts to promote and encourage sustainable land management (SLM) among smallholder farmers should be integrated into river basin planning, as an integral part of balanced water infrastructure portfolios.

b) Sustainable land management interventions in the Upper Tana Basin should be designed and selected not just on the basis of financial profitability, but also taking account of what farmers have available to them and what they require as regards land management inputs and outputs. The most preferred land management practices are not necessarily those that yield the highest yield gains, generate the greatest income, or entail the lowest costs (the characteristics that would traditionally be deemed important when SLM measures are appraised). A range of other considerations come into play, such as additionality and co-benefits, opportunity costs, cashflow and liquidity, time preference, risk and uncertainty. Unless these broader needs, constraints and preferences are identified, and addressed in the land management 'solutions' that are presented to farmers, the resulting interventions are unlikely to be acceptable, effective or sustainable in practice.

c) In some cases, the SLM measures that are 'best' for securing downstream water services may be neither financially profitable nor economically feasible at the farm level. Additional benefits, rewards or compensation may need to be provided, and justified as transfers that are being made on public interest grounds to secure broader water benefits (and/or avoid wider costs, losses and damages). Indeed, this principle and practice is already widely accepted, as evidenced by the large number of actions to address land degradation and develop payments for watershed services schemes that are being implemented in Kenya, including, in the Upper Tana Basin, the Nairobi Water Fund.

d) Such payment schemes or support facilities are, however, unlikely to be effective if they are based on cash payments, grants or technical assistance alone. Farmers are not always able to choose the 'first best' land management options that they consider to be the most effective in halting land degradation or the most desirable in economic terms, but undertake those that they are actually able to accomplish given their physical and socio-economic circumstances, land and resource endowments, market access and interactions. Efforts also need to be made to overcome the structural economic conditions that constrain, discourage or disempower farmers from investing in SLM (for example lack of investment capital, high levels of risk and uncertainty, seasonal food and cash shortages, weak labour markets, low output prices, and inability to access or afford inputs).

REFERENCES

Atampugre, G. (2011) Cost benefit analysis of soil and water conservation technologies applicable to green water management in the Saba Saba sub-catchment of the Upper Tana catchment in Kenya. Thesis submitted in partial fulfilment of the degree of Master of Science in International Development Studies, Wageningen University.

Baker, T., Kiptala, J., Olaka, L., Oates, N., Hussain, A. and M. McCartney (2015) Baseline review and ecosystem services assessment of the Tana River Basin, Kenya. IWMI Working Paper 165, International Water Management Institute (IWMI), Colombo.

Barbier E. 2000. The economic linkages between rural poverty and land degradation: some evidence from Africa. Agriculture, Ecosystems and Environment 82(1-3): 355-370.

Barnard, J., Manyire, H., Tambi E. and B. Solomon (2015) Barriers to scaling up/out climate smart agriculture and strategies to enhance adoption in Africa. Forum for Agricultural Research in Africa (FARA), Accra

Bryant, B. (2015) Ecosystem Services Assessment and Valuation of Proposed Investments for the Upper Tana-Nairobi Water Fund: A Technical Appendix to the Upper Tana-Nairobi Water Fund Business Case. The Natural Capital Project, Stanford University.

Bunyasi, M., Onywere, S. and M. KIgome (2013) Sustainable Catchment Management: Assessment of Sedimentation of Masinga Reservoir and its Implication on the Dam's Hydropower Generation Capacity. International Journal of Humanities and Social Science 3(9): 166-179.

Dijkshoorn, K., Macharia, P., Huting, J., Maingi, P. and C. Njoroge (2011) Soil and Terrain conditions for the Upper Tana River catchment, Kenya. Green Water Credits Report 11 / ISRIC Report 2010/09b, ISRIC – World Soil Information, Wageningen.

Droogers, P., Hunink, J., Kauffman, J. and G. van Lynden (2011) Costs and Benefits of Land Management Options in the Upper Tana, Kenya; Using the Water Evaluation and Planning system – WEAP. Green Water Credits Report 14, ISRIC – World Soil Information, Wageningen.

Emerton L. (2014) Bringing the economics of land degradation back to the farm level: A conceptual framework for addressing the costs and benefits of sustainable land management. CIAT Working Document No. 226, International Center for Tropical Agriculture (CIAT), Cali.

Emerton L. (2016) Assessing the economic costs, benefits and drivers of sustainable land management for farmers in Ntcheu District, Malawi and Lushoto District, Tanzania. CIAT Working Paper, International Center for Tropical Agriculture (CIAT), Cali.

Emerton, L. and J. Gicheha (2017) Summary of findings: survey to assess farmers' economic perceptions, preferences and drivers of sustainable land management in the Upper Tana catchment, Kenya. International Centre for Tropical Agriculture (CIAT), Nairobi.

FAO (2007) TerrAfrica: A vision paper for Sustainable Land Management in Sub-Saharan Africa. Food and Agriculture Organisation of the United Nations, Rome.

FAO (2010) "Climate-Smart" Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation. Food and Agriculture Organization of the United Nations (FAO), Rome.

Gebremedhin, B. (2004) Economic incentives for soil conservation in the East African countries. Paper presented at 13th International Soil Conservation Organisation Conference, Brisbane.

Geertsma, R., Wilschut, L. and J. Kauffman (2009) Baseline Review of the Upper Tana, Kenya. Green Water Credits Report 8, ISRIC - World Soil Information, Wageningen.

Giordano, M. (2003) Economics and soil conservation on sloping lands: Nine hypotheses for MSEC project implementation and research. In Maglinao, A., Valentin, C., and F. Penning de Vries (eds) From soil research to land and water management: Harmonizing people and nature. Proceedings of the IWMI-ADB Project Annual Meeting and 7th MSEC Assembly, Bangkok.

Hunink, J. and P. Droogers (2015) Impact Assessment of Investment Portfolios for Business Case Development of the Nairobi Water Fund in the Upper Tana River, Kenya. Report 133, FutureWater, Wageningen.

Hunink, J., Immerzeel, W. and P. Droogers (2009) Green Water Credits for the Upper Tana Basin, Kenya. Phase II – Pilot Operations. Biophysical assessment using SWAT. Report 84, FutureWater, Wageningen.

Hunink, J., Niadas, I., Antonaropoulos, P., Droogers, P. and J. de Vente (2013) Targeting of intervention areas to reduce reservoir sedimentation in the Tana catchment (Kenya) using SWAT. Hydrological Sciences Journal, 58 (3), 600-614.

ICRAF (2011) Pro-poor Rewards for Environmental Services in Africa 2008-2011. World Agroforestry Centre (ICRAF), Nairobi.

ISRIC (2017) Green Water Credits Pilot in Kenya. ISRIC - World Soil Information, Wageningen. http://www.isric.org/projects/green-water-credits-pilot-kenya, accessed 1 November 2017.

Kabubo-Mariara, J. (2015) Does Institutional Isolation Matter for Soil Conservation Decisions? Evidence From Kenya. SAGE Open January-March 2015: 1–9.

Kamfor (2014) Upper Tana Natural Resources Management Project (UTaNRMP) Baseline Survey Report. Report submitted to IFAD and Ministry Of Environment, Water and Natural Resources by Kamfor Company Limited, Nairobi.

Kassie, M., Teklewold, H., Jaleta, J., Marenya, P. and O. Erenstein (2015) Understanding the adoption of a portfolio of sustainable intensification practices in eastern and southern Africa. Land Use Policy 42: 400-411.

Kassie, M., Yesuf, M. and G. Köhlin (2008) The Role of Production Risk in Sustainable Land- Management Technology Adoption in the Ethiopian Highlands. EfD Discussion Paper 08-15, Environment for Development, University of Gothenburg and Resources for the Future in Washington DC.

Kauffman, S., Droogers, P., Hunink, J., Meaniki, B., Muchena, F., Gichere, P., Bindraban, P., Onduru, D., Cleveringa, R. and J. Bouma (2014) Green Water Credits – exploring its potential to enhance ecosystem services by reducing soil erosion in the Upper Tana Basin, Kenya. International Journal of Biodiversity Science, Ecosystem Services & Management 10(2): 133-143.

Kizito, F., Cordingley, J., Nganga, K., Bossio, D. and F. Kihara (2014) Using an ecosystems approach for securing water and land resources in the Upper Tana Basin. Final Technical Report: WLE Innovation Fund 2013/2014, International Centre for Tropical Agriculture (CIAT), Nairobi.

Knoop L., Sambalino F. and F. Van Steenbergen (2012) Securing Water and Land in the Tana Basin: a resource book for water managers and practitioners. 3R Water Secretariat, Wageningen

KWTA (2015) Kenya Water Towers Status Report. Kenya Water Towers Agency (KWA), Nairobi.

Leisher, C. (2015) Maragua and Thika/Chania Baseline Survey Results. The Nature Conservancy (TNC).

Mati, B. (2016) Overview of the: policy, legislative and institutional frameworks for sustainable land management in the public sector in Kenya. TerrAfrica Project, NEPAD Planning and Coordinating Agency, Johannesburg.

McCartney, M., Foudl, S., Mutuwatte, L., Sood, A., Simons, G. and K. Vercruysse (in press) Water, Natural and Built infrastructure, and Ecosystem Services in the Tana River Basin. IWMI Research Report, International Water Management Institute (IWMI), Colombo.

MENR (2016) Kenya Strategic Investment Framework for Sustainable Land Management 2017-2027. Ministry of Environment and Natural Resources, Nairobi.

Mucheru-Muna, M., Pypers, P., Mugendi, D., Kung'u, J., Mugwe, J., Merckx, R. and B. Vanlauwe (2010) A staggered maize–legume intercrop arrangement robustly increases crop yields and economic returns in the highlands of Central Kenya. Field Crops Research 115(2): 132–139.

Mueni, P. (2016) Climate Change Impacts On Water Resources Over The Upper Tana Catchment Of Kenya. Dissertation Submitted in Partial Fulfillment of the Requirements for the Award of the Degree of Master of Science in Meteorology of the University of Nairobi.

Muriuki, J. and P. Macharia (2011) Inventory and Analysis of Existing Soil and Water Conservation Practices in the Upper Tana. Kenya. Green Water Credits Report 12, ISRIC – World Soil Information, Wageningen.

Mwangi J., . Mboya, T. and M. Kihumba (2001) Improved Maize Production in Central Kenya with Adoption of Soil and Water Conservation Measures. Seventh Eastern and Southern Africa Regional Maize Conference, Nairobi.

Mwangi, J., Shisanya, C., Gathenya, J., Namirembe, S. and D, Moriasi (2015) A modeling approach to evaluate the impact of conservation practices on water and sediment yield in Sasumua Watershed, Kenya. Journal of Soil and Water Conservation 70(2): 75-90.

Njogu, I. and J. Kitheka (2017) Assessment of the influence of rainfall and river discharge on sediment yield in the Upper Tana catchment in Kenya. Hydrol Current Res 2017, 8 (1): 1000263.

Ogada, M., Mwabu, G. and D. Muchai (2014) Farm technology adoption in Kenya: a simultaneous estimation of inorganic fertilizer and improved maize variety adoption decisions. Agricultural and Food Economics 2(12).

Okeyo, A., Mucheru-Muna, M., Mugwe, J., Ngetich, K., Mugendi, D., Diels, J. and C. Shisanya (2014) Effects of selected soil and water conservation technologies on nutrient losses and maize yields in the central highlands of Kenya. Agricultural Water Management 137: 52-58.

Okoba, B. and G. Sterk (2006) Quantification of visual soil erosion indicators in Gikuuri catchment in the central highlands of Kenya. Geoderma 134(1-2): 34–47.

Onduru, D. and F. Muchena (2011) Cost Benefit Analysis of Land Management Options in the Upper Tana. Kenya. Green Water Credits Report 12, ISRIC – World Soil Information, Wageningen.

Onduru, D., Muchena, F., Njuguna, E. and S. Kauffman (2013) Financial Efficiency and Intergenerational Equity of Soil and Water Conservation Measures in Kenya. Greener Journal of Geology and Earth Sciences 1(2): 43-62.

Pender J., Place F, and S. Ehui (2006) Conceptual framework and hypotheses. In: Pender J., Place F, and S. Ehui (eds) Strategies for sustainable land management in the East African highlands. International Food Policy Research Institute, Washington DC.

Pettinotti, L. (2016) Kimakia sub catchment household survey – a land management analysis. Unpublished report, Basque Centre for Climate Change (BC3), Bilbao

Porras, I., Grieg-Gran, M. and G. Meijerink (2007) Farmers' adoption of soil and water conservation: potential role for payments for watershed services. Green Water Credits Report 5, ISRIC – World Soil Information, Wageningen.

PRESA (2017) Upper Tana Basin: Caring for Kenya's largest river. Pro-poor Rewards for Environmental Services in Africa (PRESA), World Agfroforestry Centre (ICRAF), Nairobi. http://presa.worldagroforestry.org/where-we-work/kenya-mt-kenya-east/ accessed October 1 2017.

Pretty, J., Toulmin, C. and S. Williams (2011) Sustainable intensification in African agriculture. International Journal of Agricultural Sustainability 9:5–24.

Said M., Okwi P., Ndenge'e G., Agatsiva J. and X. Kilele (2007) Nature Benefits in Kenya: an Atlas of Ecosystem and Human Well-Being. World Resource Institute, Department of Resource Surveys and Remote Sensing, Ministry of Environment and Natural Resources, Central Bureau of Statistics, Ministry of Planning and National Development, Kenya and International Livestock Research Institute, Nairobi.

Saiz G., Wandera, F., Pelster, D., Ngetich, W., Okalebo, J., Rufino, M. and K. Butterbach-Bahl (2016) Long-term assessment of soil and water conservation measures (Fanya-juu terraces) on soil organic matter in South Eastern Kenya. Geoderma 247:1-9.

Simons, G., Buitling, J., Drooge3rs, P. and J. Hunink (2017) Impacts of climate change on water and sediment flows in the Upper Tana Basin, Kenya. Report 161, FutureWater, Wageningen.

Sood, A., Muthuwatta, L., Sandeepana Silva N. and M. McCartney (2017) Understanding the Hydrological Impacts of Climate Change in the Tana River Basin, Kenya. IWMI Working Paper No. 178, International Water Management Institute (IWMI), Colombo.

Tanui, J. (2006) Incorporating a land-care approach into community land management efforts in Africa: A case study of the Mount Kenya region. African Highlands Initiative (AHI) Working Paper series No. 19, World Centre for Agroforestry (ICRAF), Nairobi.

Tanui, J., Froenveld, R., Klomp, J., Mowo, J. and E. van Ierland (2013) Explaining investments in sustainable land management: The role of various income sources in the smallholder farming systems of western Kenya. presented at the 4th International Conference of the African Association of Agricultural Economists, Hammamet.

TARDA (2017) About the Tana & Athi Rivers Development Authority. https://www.tarda.co.ke/about-tarda/ accessed October 15, 2017.

TNC (2015) Upper Tana-Nairobi Water Fund Business Case. The Nature Conservancy (TNC), Nairobi.

UNEP (2012) The Role and Contribution of Montane Forests and Related Ecosystem Services to the Kenyan Economy. United Nations Environment Programme (UNEP), Nairobi.

van Beukering, P. and H. de Moel (eds) (2015) The Economics of Ecosystem Services of the Tana River Basin: Assessment of the impact of large infrastructural interventions. IVM Institute for Environmental Studies, VU University Amsterdam.

Vogl, A. and S. Wolny (2015) Developing cost-effective investment portfolios for the Upper Tana-Nairobi Water Fund, Kenya. The Natural Capital Project, Stanford University.

Vogl, A., Bryant, B., Hunink, J., Wolny, S., Apse, C. and P. Droogers (2017) Valuing investments in sustainable land management in the Upper Tana River basin, Kenya. Journal of Environmental Management 195(1): 78-91.

Wachira, S. (2013) Evaluation of potential sustainable land management practices to enhance watershed ecosystem services in upper tana catchment: a case study of Kirurumwe River, Ena Basin in Embu County, Kenya. Research paper submitted in partial fulfilment of requirements, for the degree of Master of ArtS in Environmental Planning and Management, University of Nairobi.

Wilschut, L. (2010) Land Use Map of the Upper Tana, Kenya; Based on remote sensing. Green Water Credits Report 9, ISRIC - World Soil Information, Wageningen.