Green Water Credits

The spark has jumped the gap

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Proof of concept

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Green Water Credits is a mechanism to pay rural people for specified land and soil management activities that determine all fresh water resources at source. This service is presently unrecognized and un-rewarded. This proof-of-concept project is supported by the International Fund for Agricultural Development (IFAD) and the Swiss Agency for Development and Cooperation (SDC)

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MAIN POINTS

Water scarcity is undermining development, food security, human welfare, and ecosystems; shortage is increasingly felt in cities. Better soil and water management can greatly increase the resilience of farming systems and improve water availability downstream. By 2025, 2.8 billion people will be suffering absolute water shortage and two thirds of the world's people will be under water stress. Globally, two thirds of renewable fresh water is *green water,* held in the soil; only one tenth is accessible stream flow and groundwater, of which 70 per cent is used for irrigation. But nearly all investment goes into abstraction from streams and groundwater; replenishment is neglected. Meeting the Millennium Goal on hunger means doubling water use by crops by 2050; irrigation cannot do it alone. A policy shift is required to improve water-use efficiency in rain-fed farming and recharge streams and groundwater.

Green water **resources can be much increased and downstream delivery of fresh water better regulated by two fundamental improvements in rain-fed farming: increasing the infiltration of rainwater, thereby cutting runoff; and reducing unproductive evaporation.** More infiltration means banking water in soils and aquifers, and better river base flow; less runoff means, less erosion, less flooding and less siltation. Low-cost soil and water management packages can significantly increase available water resources.

Poverty is a severe constraint. Farmers are aware of their private benefits from soil and water conservation but they need immediate as well as on-going returns for their labour and material inputs. The Upper Tana is occupied by many smallholders, mostly poor, with limited access to markets, and low prices for their produce. Poverty drives a preference for short-term benefits, so that the cost of conservation measures outweighs their private benefits. Further incentives are needed to ensure wide adoption - and maintenance.

Green Water Credits are payments for water management services by farmers. These services are currently unrecognised and unrewarded. Quite small cash transfers from downstream water users will enable farmers to adopt sustainable management of land and water; at the same time they will combat rural poverty by diversifying income. The proof-of-concept demonstrates:

a. The link between upstream land use and management and downstream water supply, river regulation, and siltation of reservoirs;
b. Practical ways to assess the resource, optimise water allocation, and calculate the costs and benefits;
c. The cost of simple and effective soil management practices may be covered by the additional water revenues. For the Upper Tana, annual water benefits are $US 12-95 millions and costs 2-20 millions; for a 20 per cent adoption scenario, water benefits are $US 6-48 millions (3-7 millions under the most pessimistic assumptions) and costs 0.5-4.3 millions (2-8.5 millions under the most pessimistic assumptions).

Green Water Credits supports the current water reform in Kenya by providing a market-based mechanism by which many of the goals of reform may be achieved. The National Water Resources Management Plan and the Water Act 2002 assign an economic value to water in all its competing uses; and Green Water credits establishes a market between water users and water services providers.

In the Tana basin, all water users (hydro-power generation, municipal water utilities, irrigators) have substantial, and growing, un-met demands. Key issues for hydro-power are low reservoir levels, and high silt loads that shorten the life of reservoirs and turbines. Most of Nairobi's water comes from the Upper Tana and demand is projected to increase steeply. Climate change will significantly increase un-met demands, especially for irrigation.

Immediate, nationally-significant gains in power generation and urban water supply may be realised by arresting siltation of reservoirs. For instance, the Masinga may have lost 30 per cent of its capacity over 20 years up to 2002. Targeting siltation involves relatively small areas and few farmers; resources and managerial capacity are already available for a pilot application of Green Water Credits in the reservoir catchments.

Operation of Green Water Credits will depend on cooperation among farmers; good examples are already in place.

1. Soil and water conservation practices are more effective if neighbours work together as water services groups;
2. It will be easier to make and service contracts with groups rather than with individual smallholders;
3. Farmers' groups can be self-policing in respect of compliance with contracts.

Technical procedures have been developed to assist water resources assessment, allocation, and financial transactions:

1. Well-tried basin hydrology models are already available; however, these require specialist professional staff;
2. The Water Evaluation and Planning (WEAP) model has been developed as a powerful yet easy-to-use tool for planning and water allocation; it integrates information on water supply, demand and cost and displays management scenarios. WEAP is free and can be operated with very little training;
3. A low-cost, cash transaction system, making use of the mobile phone network, enables reliable, documented and low-cost cash transfer between individuals or groups anywhere in the country.

Capacity-building is needed: for local water services providers groups, for an intermediary organisation providing a platform for negotiations and management of contracts, and for water resources managers that must translate present and future water requirements into a rolling plan for implementation.

ACKNOWLEDGEMENTS

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‘The spark has jumped the gap’ is borrowed from GTZ (1992).

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Acronyms and abbreviations

KARI	Kenya Agricultural Research Institute
KenGen	Kenya Electricity Generating Company Ltd
NALEP	National Agriculture and Livestock Extension Programme
NWC	Nairobi Water Company
SWAT	Soil And Water Assessment Tool
WEAP	Water Evaluation and Planning system
WOFOST	World Food Studies model
WRMA	Water Resources Management Authority

1 Introduction

1.1 Green Water Credits

Green Water Credits are payments for water management services by farmers - services that are currently unrecognized and unrewarded. Benefits to poor rural people drive this initiative; at the same time, it safeguards fresh water for everyone.

By 2025, some 2.8 billion people will be living in countries with absolute water scarcity, and two thirds of the world population could be under conditions of water stress – the threshold for meeting the water requirements for agriculture, industry, domestic use, energy and the environment (UN Water 2006).

Two thirds of all fresh water is *green* water - held in the soil and used by plants. Soils also deliver *blue* water - groundwater and stream flow that can be tapped for use elsewhere (Figure 1), 70-80 per cent is used for irrigation. Nearly all investment goes into abstraction of blue water; replenishment at source is neglected. Better soil and water management, let us call it *green water management,* can greatly increase the resilience of farming systems and water supplies downstream.

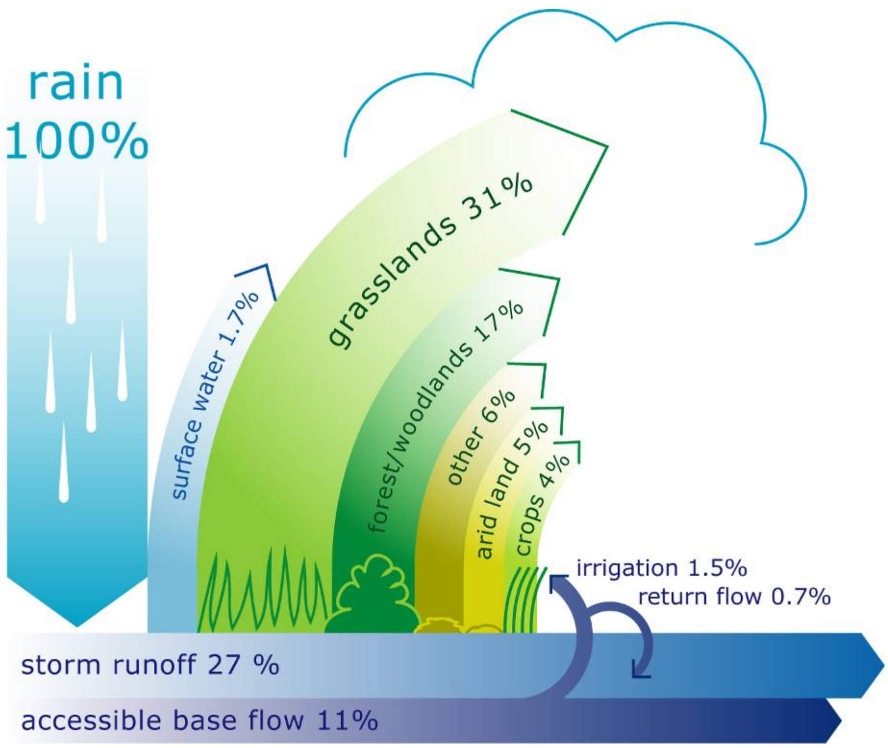


Figure 1: ***Green* and *blue* water, global flows**
The irrigation value also includes use of non-renewable groundwater
Data from Falkenmark and Rockström 2004

Farmers manage water at source by looking after the land. Depending on management, the resource may be increased three-fold, or destroyed. The costs of management failure are floods and drought, siltation of reservoirs, loss of food and water security, and rural poverty that drives people to cities and across borders.

Management failure stems from a market failure. While *green* water is harvested as crops, the benefits of *blue* water are reaped downstream. If there is a market in water, it is confined to delivery to the consumer; at source, water is taken for granted! Green Water Credits rectify this market failure by payment for water management services (Figure 2).

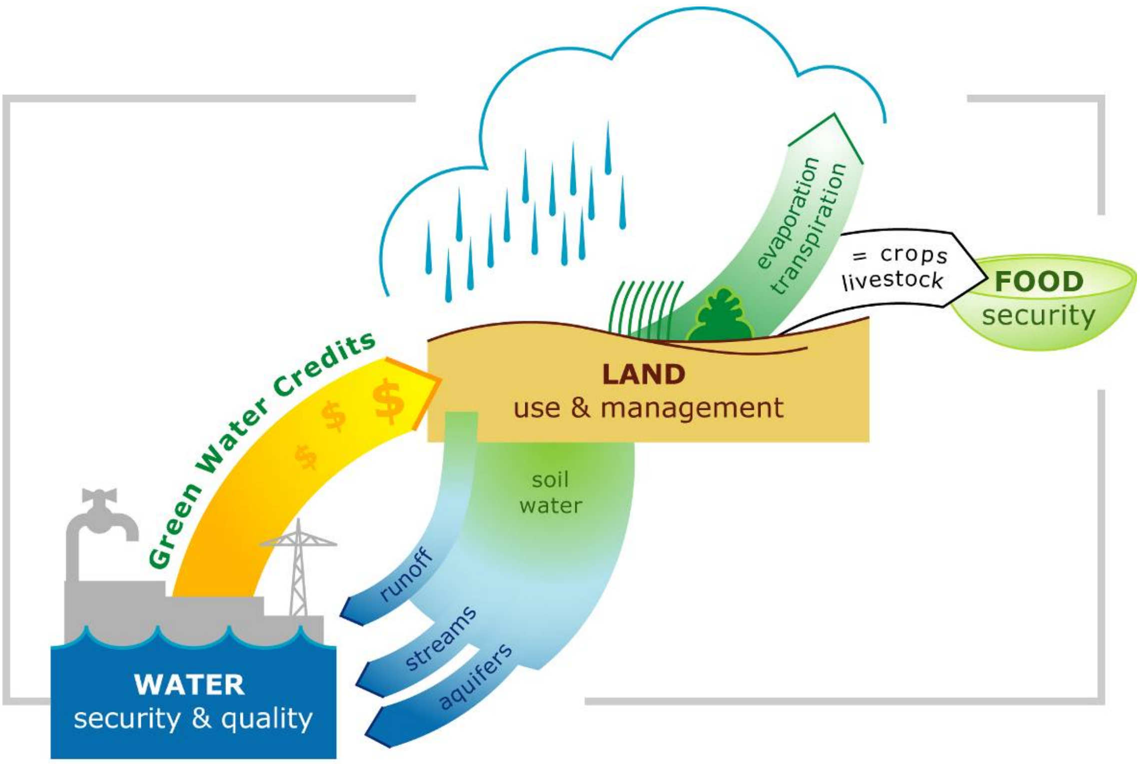


Figure 2: Green Water Credits bridge the incentive gap

If water users are to pay for what they now receive free, they will need to see: first, a clear link between land use and downstream water supply and water quality, flooding, and siltation of reservoirs; then, reliable measurement of the resource and how it can be optimized by land management; appraisal of the worth of water in all its competing uses, and the costs of floods, siltation, and ill health from lack of clean water; and finally, a mechanism to specify optimal management, negotiate a fair price, establish that the work is done, and pay for the service.

Pros and cons

- Green water management can achieve improvements in water supply and water quality that cannot be achieved at a comparable cost by engineering and water treatment.
- Green water management brings direct benefits to farmers: better and more reliable crops, and better prices for better-quality products. But these may not be enough to cover the extra costs; Green Water Credits bridge the incentive gap.
- Small cash injections can have a significant multiplier in poor communities.
- Investment in the land and in skilled managers depends on legal arrangements such as secure tenure and water rights to protect that investment; it may also encourage action to secure land and water rights.
- Failure of Green Water Credits - through inadequate preparation, institutional arrangements or funding - will breed disillusion that will be hard to recoup.

Operational steps

1. Assess, from all sides, existing land and water rights and the competing claims on water resources. *Who has the right to modify existing rights?*
2. Assess the water resource, the demands upon it, its value in all its competing uses, the costs of mismanagement, the extent to which green water management can optimize the resource, and the costs of this management; seek optimum allocation. *What has been tried already?*
3. Establish a platform for negotiation between the parties; ensure that each is well informed; and agree on a fair price.
4. Establish a mechanism for collection and payment of credits, verification of claims, and settlement of disputes. Payments may be financed by a mix of water users and public utilities, insurers, and general taxation. *What institutions are in place that can handle the new initiative?*

1.2 *Green* and *blue* water resources

Rainfall may run off the ground surface (Figure 3) or infiltrate into the soil (Figure 4). Water in the soil may be used by plants (*green* water), or evaporate unproductively from the ground surface, or it may drain deeply to recharge groundwater and stream-flow (*blue* water). Land use and management determine the partitioning between runoff and infiltration, and the quantity and quality of stream-flow and groundwater.

Figure 3: Runoff during a rainstorm

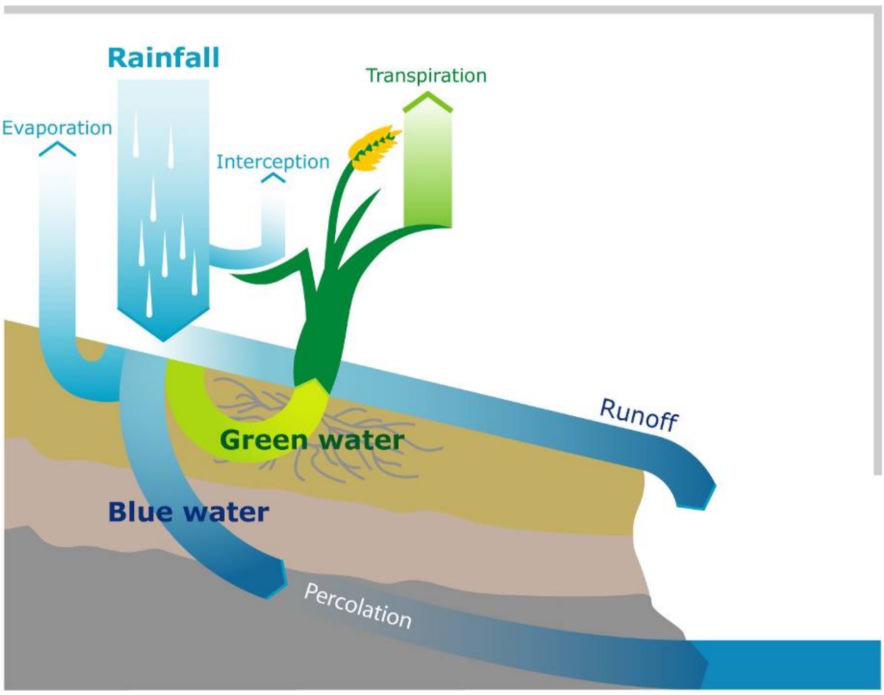


Figure 4: Partitioning of rainwater into *green* and *blue* water flows

Human well-being depends on *green* water for farm and forest production; on *blue* water for irrigation, livestock and domestic use, hydro-power and industry (Figure 5); and on environmental flows to maintain ecosystem services including the water cycle and climate regulation. Habitat, economy and society depend on the whole water cycle but water resources policy and management have focused almost exclusively on abstraction of accessible *blue* water from rivers, lakes and groundwater; replenishment is neglected. The looming water crisis demands integrated management of the whole water cycle (Box 1) - starting with rainwater.

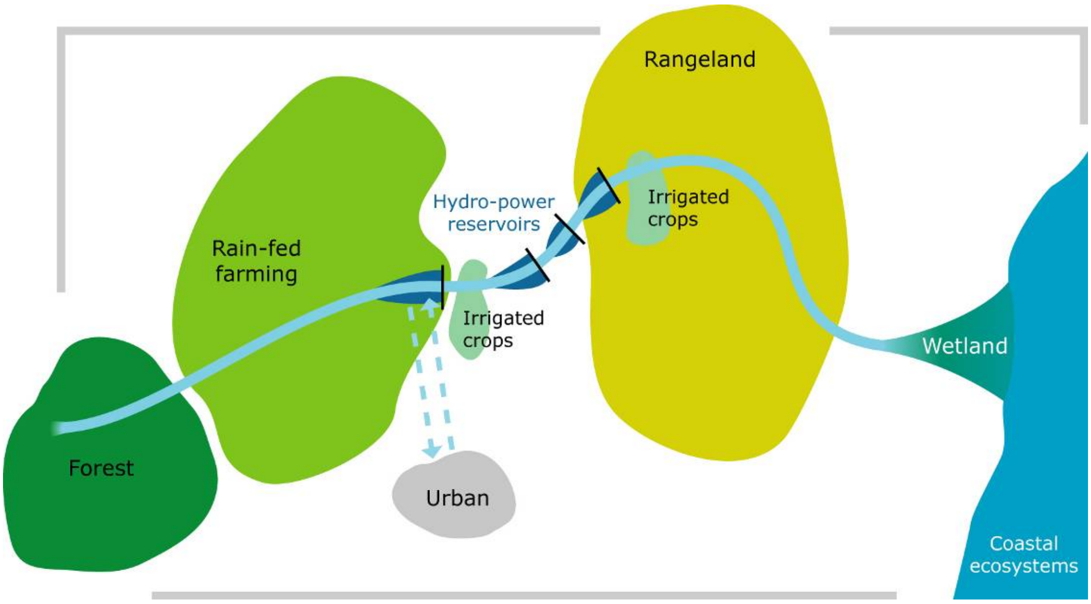


Figure 5: Water users at basin level

Box 1: Integrated water resource management

Integrated water resource management is based on the Dublin Principles (adopted at the 1992 International Conference on Water and Environment, in Dublin). It is 'a process that promotes the coordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems' (GWP 2000). This means linking the management of those parts of the natural world that determine the supply and quality of water, including:

> *Land and water, recognising that land use affects water resources;*
>
> *Upstream and downstream interests, as the practices of people in the catchment affect the quantity and quality of water for downstream users;*
>
> *Surface water and groundwater, recognising that streams and aquifers are connected;*
>
> *Green water and blue water, as water management has focused on water in rivers and aquifers at the expense of water used for plant growth;*
>
> *Water quantity and water quality, so that the usability of water for different purposes is maintained or enhanced;*
>
> *Water and waste water, by providing alternative supplies with treatment and re-use of flows traditionally considered waste, such as brackish sources and sewage.*

People decide how water is used - or misused. Linking with the social dimension may be achieved through:

> *Involving all parties in decision-making, providing mechanisms for evaluating trade-offs and avenues for conflict resolution – which requires capacity-building so that all parties have the knowledge and skills needed to participate;*
>
> *Making available adequate information on the biophysical, economic and social characteristics of the catchment to support decision making;*
>
> *Influencing water users to make choices based on the real value of water and the need for long-term viability of the resource.*

Water has an economic value in all its competing uses. Past failure to recognise its economic value has led to wasteful and environmentally damaging use. Green Water Credits links all aspects of integrated water management by providing a market-based mechanism for sustainable management of the resource.

1.3 The land and water problem

1.3.1 Competing claims and management by default

Two billion people are living in absolute poverty. Seventy per cent of them depend on rain-fed farming; there is urgent need for strategies to secure and diversify their livelihoods. Furthermore, future production of food, raw materials and bio-fuel will continue to depend mainly on rain-fed farming. Irrigation already takes the lion's share of *blue* water and faces competing claims from urban water supply and environmental flows (IWMI 2007).

It is the upstream land users who deliver the water for use downstream. Poor rainwater management in farmers' fields means that three quarters of the rainfall may be lost - as runoff and evaporation from bare soil. Runoff carries away the topsoil; floodwaters cause damage to life and property, and fill reservoirs with sediment that reduces water storage and power generation (Table 1).

Table 1: Consequences of poor rainwater management

Upstream	*Downstream*
Less *green* water for crops, exacerbating dry spells and drought: yield losses, food insecurity, loss of livelihoods	Food insecurity
Soil erosion Flash floods Damage to local infrastructure	Floods Damage to infrastructure Siltation of river channels and reservoirs
Falling water table, failure of wells and springs, reduced river base flow	Uncontrolled peak river flows, reduced or no dry-season flow Less hydropower; damage to turbines Less and less-reliable urban water supply Less water for irrigation Less water for natural ecosystems, especially in the dry season

Land use and management is both the problem and the solution. Green water management enhances infiltration into the soil and, so, abates overland flow; unproductive evaporation from the soil can also be reduced. This means more water for crops, and more deep percolation to recharge groundwater and stream-flow (Table 2).

Table 2: Benefits of good rainwater management

Upstream	*Downstream*
More *green* water, alleviating dry spells and drought Increased and more reliable yield (given adequate manure or fertilizer) More secure rural livelihoods	Improved food security
Less soil erosion	Less sediment and pollution in rivers Less siltation of reservoirs
Less local flooding and washouts	Flood alleviation Less damage to infrastructure
Groundwater recharge More reliable wells, springs and stream flow	More reliable river flow More hydro-power More irrigation water Improved quality and reliability of urban water supply

1.3.2 What impedes good management?

- Water management, as presently undertaken by water authorities, is essentially surface-water management - not management of the whole resource;
- Water management by farmers and graziers is incidental; they are paid for their crops and livestock, not for delivering water;
- Land users have limited access to training in green water management and they are largely unaware of the downstream effects of their activities;
- Land users often cannot afford to implement best practice - in the short term, the costs are greater than the returns;
- Land and water rights are not sufficient to motivate investment in green water management.

1.3.3 A market-based mechanism

Green Water Credits is a mechanism to reward land users for specified soil and water management activities that determine the supply of fresh water at source. These activities are presently unrecognized and un-rewarded. Establishment of a market in which water users buy, and land and water managers sell, this service will support integrated water management. Green Water Credits will also provide reliable diversification of rural incomes, enabling communities to adapt to economic, social and environmental change through asset-building in the shape of stable soils, more reliable local water supply, improved crops and infrastructure.

The strategy is to introduce a market-based mechanism to support improved water management at source – *green water management*. This depends on demonstration of the downstream benefits of green water management; development of sustainable practices appropriate to local conditions; negotiation of fair rewards for their implementation; and establishment of a mechanism whereby downstream beneficiaries pay for these services in the long term.

1.4 Proof-of-concept

1.4.1 Aim

The proof-of-concept assesses the viability and feasibility of the Green Water Credits process in four domains (Figure 6): *green* and *blue* water management, livelihoods, governance (institutions, legislation and regulations), and operational requirements.

Figure 6: Green Water Credits domains

1.4.2 Key issues

It is known that the regulation of water supply achieved by green water management cannot be achieved at a comparable cost by engineering and water treatment; that fair payment ensures that a job is done, and done well; and that small cash injections can have a significant multiplier in poor communities. But sustainability is an important issue; lasting incentives are required, rather than a one-off gesture, so the mechanism has to be embedded in reform of the whole water sector.

The following are required for Green Water Credits to be adopted:

1. Demonstrate the link between upstream land and water management and downstream water supply, water quality and sediment load;
2. Quantify water resources available under various management options;
3. Value the uses of water within the basin and the costs of droughts, floods, erosion, siltation, and the diseases caused by a lack of clean water. This enables cost-benefit analysis of various management options;
4. Establish the terms under which buyers and sellers of water management services are willing to participate;

5. Develop procedures to specify management practices, agree on a fair price, and establish that the work is done, and collect and pay credits.

Payments may be financed by a mix of levies on water users, by insurers seeking to reduce their exposure to environmental risks, and through general taxation. Investment in the land and in skilled managers of the land may encourage legal arrangements that will be needed to protect that investment, for instance secure land tenure and water rights. International finance may be used to kick-start the virtuous cycle.

The following issues are addressed in the pilot basin:

1. Strategic assessment:
   - What are the water issues?
   - What are the competing claims?
   - Existing land and water rights. Who has the right to modify them, and who has to compensate whom?
   - What has been tried already?
   - What institutions are in place that can handle the initiative?
2. Practical ways to assess the water resource, the demands upon it, the value of the resources, and costs of mismanagement;
3. The potential for green water management to increase the availability of *blue* water resources;
4. Parties' willingness to participate and the terms for this participation; platform for negotiation; ability to secure fair terms;
5. Arrangements for validation of work and settlement of disputes; mechanisms for collection and payment of credits;
6. Legal framework;
7. Managing institutions.

1.4.3 Pilot basin

Sub-Saharan Africa was chosen for the proof-of-concept, in line with SDA and IFAD priorities. The Tana Basin, in Kenya (Figure 7) was chosen on the basis of comparison of candidates within the region (Droogers and others 2006).

Figure 7: Tana basin, location

The Upper Tana has good rainfall and many farmers, so there is a big potential for improved water delivery. There are important downstream water users who are in the position to pay for water management services over the long term: hydro-power and municipal water utilities, and large-scale irrigators. Water scarcity is an emerging issue; current farm practices cause rapid runoff and soil erosion, leading to erratic river flow and a big silt load – in turn causing siltation of reservoirs, damage to turbines, and blockage or destruction of roads, bridges and culverts. Most importantly, the Government of Kenya is engaged in radical reform of the water sector. Water is now recognised as an economic good and water rights are to be assigned according to catchment management strategies. The Green Water Credits process may provide key information and a mechanism to support sustainable management of the resource.

2 Tana River Basin

2.1 Water scarcity and land degradation in Kenya

Water is scarce in Kenya and the demands on the resource press ever more strongly. Four fifths of the country is dryland; less than 8 per cent of rainfall is ultimately delivered as *blue* water compared with the global average of 38 per cent (compare Figures 1 and 8). Some comparisons with neighbouring countries in terms of present water use are listed in Table 3.

Now, less than 8 per cent of available *blue* water flow is abstracted. By 2025, more than 40 per cent of the accessible flow will be needed (Govt Kenya 2006a) which will put Kenya on a par with countries like Iran, Egypt and Saudi Arabia.

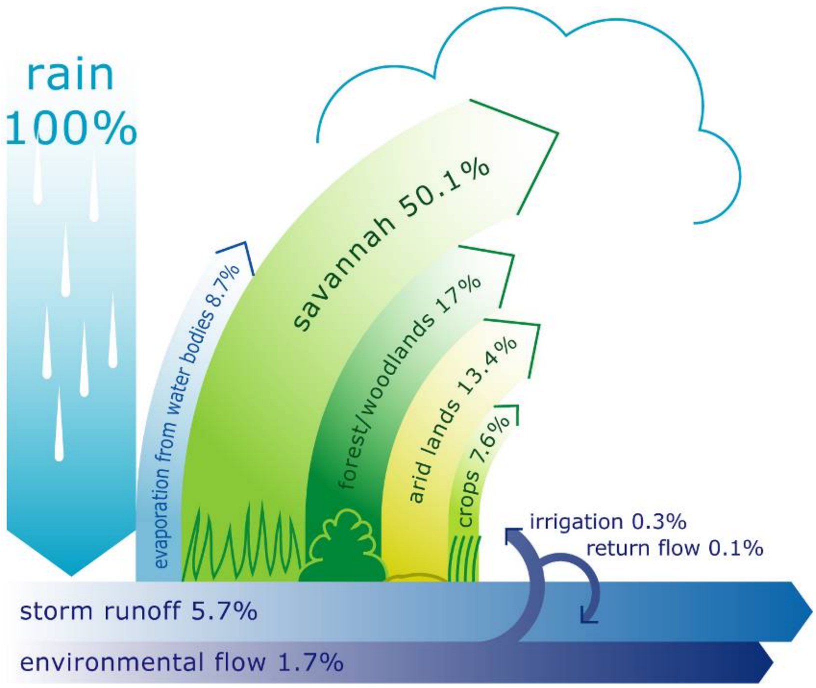


Figure 8: Kenya: *Green* and *blue* water flows
Data from Rockström and others, 2005

Table 3: Regional differences in water resources and consumption
(World Bank 2007)

	Renew-able water Bm^3/yr	*Renew-able water m^3/cap*	*Total water abstraction Bm^3/yr*	*Abstraction % of total*	*Irrigation and livestock, % abstraction*	*Domestic use, % abstraction*	*Industrial use, % abstraction*
KE	20.7	604	1.6	7.6	79	17	4
TZ	83.9	2192	5.2	6.2	91	10	0.5
ET	122.1	1712	5.6	4.6	93	6	1
UG	38.1	1353	0.3	0.8	40	45	5

Biological production (measured by net primary productivity, NPP) and cropland are tied to rainfall (Figure 9). Both are concentrated in the highlands of Central and Western Kenya which feed streams flowing west to Lake Victoria or, like the Tana, north and east to the dry lowlands.

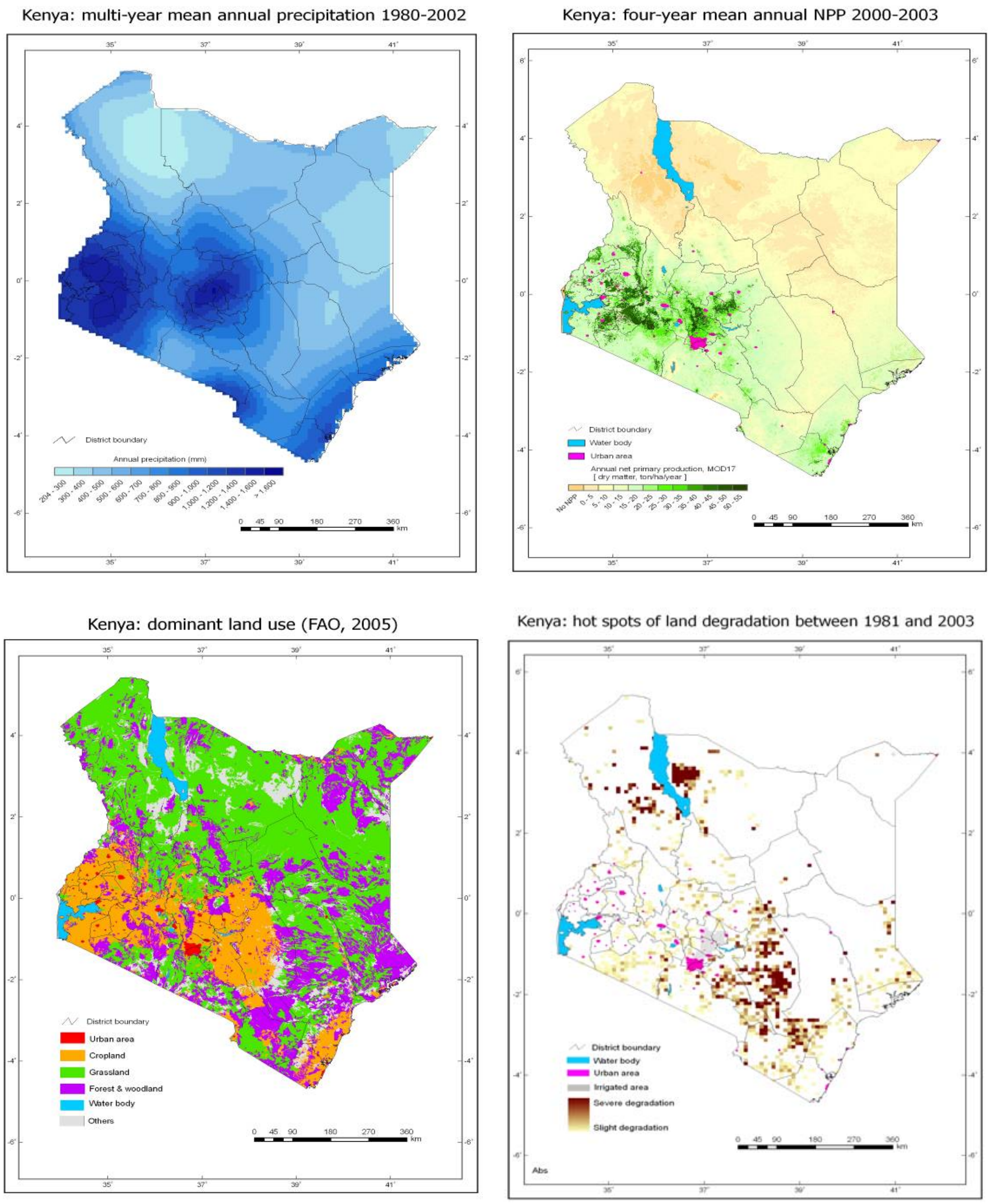


Figure 9: Kenya: mean annual rainfall, mean annual NPP 2000-2003, dominant land use, and land degradation 1981-2003
(Bai and Dent 2006)

Land degradation may be defined as a long-term decline in both NPP and rain-use efficiency (NPP per unit of rainfall). During the last 25 years, 17 per cent of the land has suffered from land degradation. Overall, NPP increased in grassland, forest and woodland - but hardly at all in cropland. Across 40 per cent of cropland it *decreased,* on average by 13 kg/ha/yr (Bai and Dent 2006). This is a concern for both food and water security; during the same period the human population more than doubled.

2.2 Land and water resources in the Tana Basin

The Tana River basin encompasses 126 028 km^2) in the Eastern part of Kenya (Figure 7). It supports a population of 5½ million of whom 4 million, some 500 000 households, live in the Upper Tana catchment (Figure 10), the *water tower* which supplies water for the 3 million people of Nairobi, and most of Kenya's power. The Upper Tana has been much changed in recent decades by the construction of five dams (Figure 11) which regulate river flow and provide hydro-power capacity and storage for urban water supplies and irrigation. The design capacity of the reservoirs is 2 330 million m^3. In comparison, the volume of the soil water reservoir in the Upper Tana is about 7 500 million m^3, and the soil recharges the groundwater reservoir which is orders of magnitude greater.

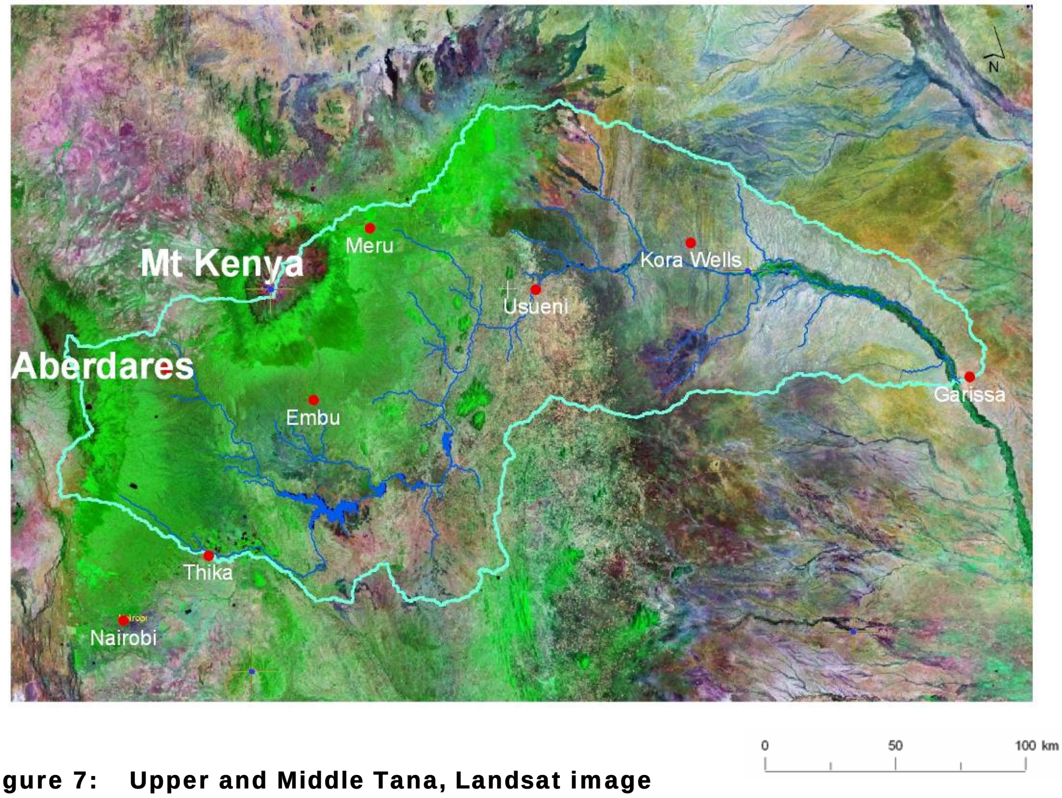


Figure 7: Upper and Middle Tana, Landsat image
True-colour image: well-vegetated, high-rainfall areas of Mt Kenya and the Aberdares Range appear green; catchment boundary overlaid in light blue, streams and reservoirs in blue

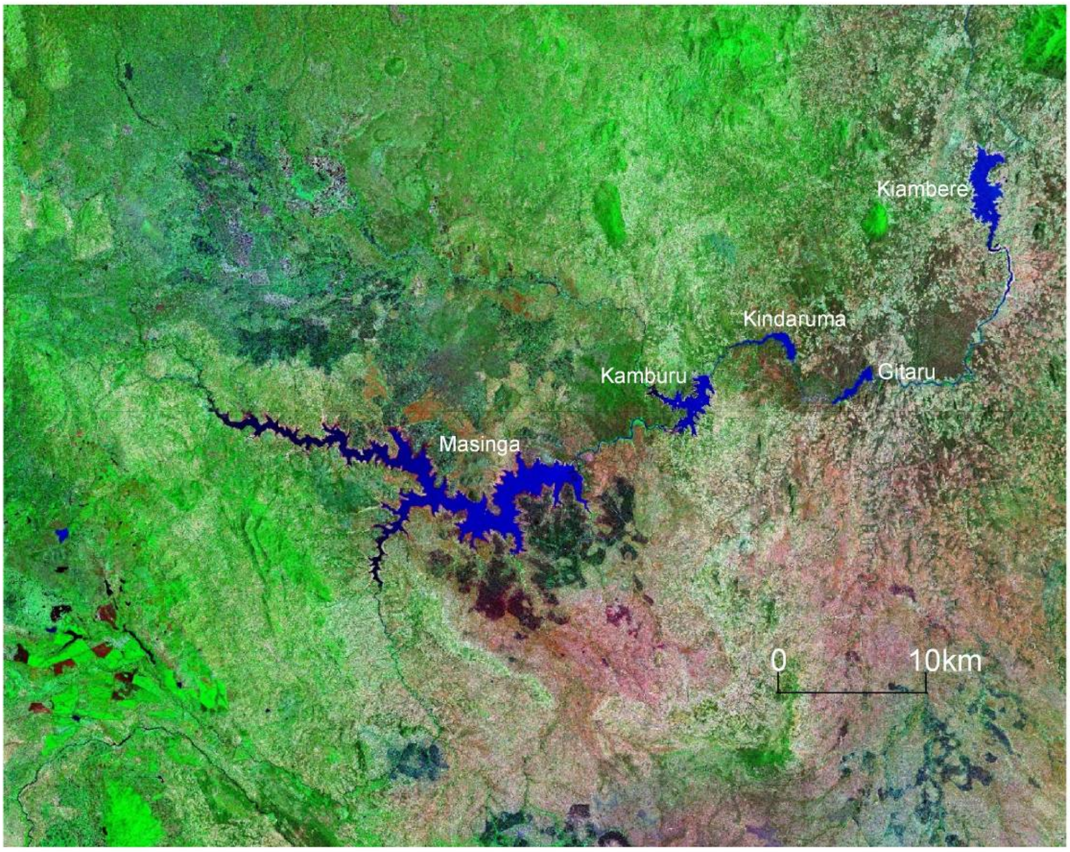


Figure 8: Upper Tana, surroundings of the main reservoirs, Landsat image

Rain-fed cropping occupies about 1 million ha, about half of the highlands (elevation above 1050m) where mean annual rainfall is greater than 700mm; the main crops are tea, coffee and maize (Figure 9). The lower-lying, drier areas are mostly rangeland.

Cropland is a soil erosion hazard. Under tea, erosion is significant during early establishment and after pruning, but much reduced after closure of the crop canopy. Coffee and maize cultivation present a severe hazard on account of the poor ground cover during most of the year; soil conservation measures currently undertaken are inadequate (Figure 10). Green water management in the *water tower* areas will have a substantial effect on water supplies downstream through measures to:

- Minimize runoff and hence, soil and bank erosion;
- Increase infiltration, to recharge groundwater and sustain stream flow;
- Minimize evaporation from bare soil, to the benefit of both green water and *blue* water flows.

Farmers in the immediate catchment of the reservoirs have the best opportunity to improve both the *blue* water supply and arrest the siltation of reservoirs.

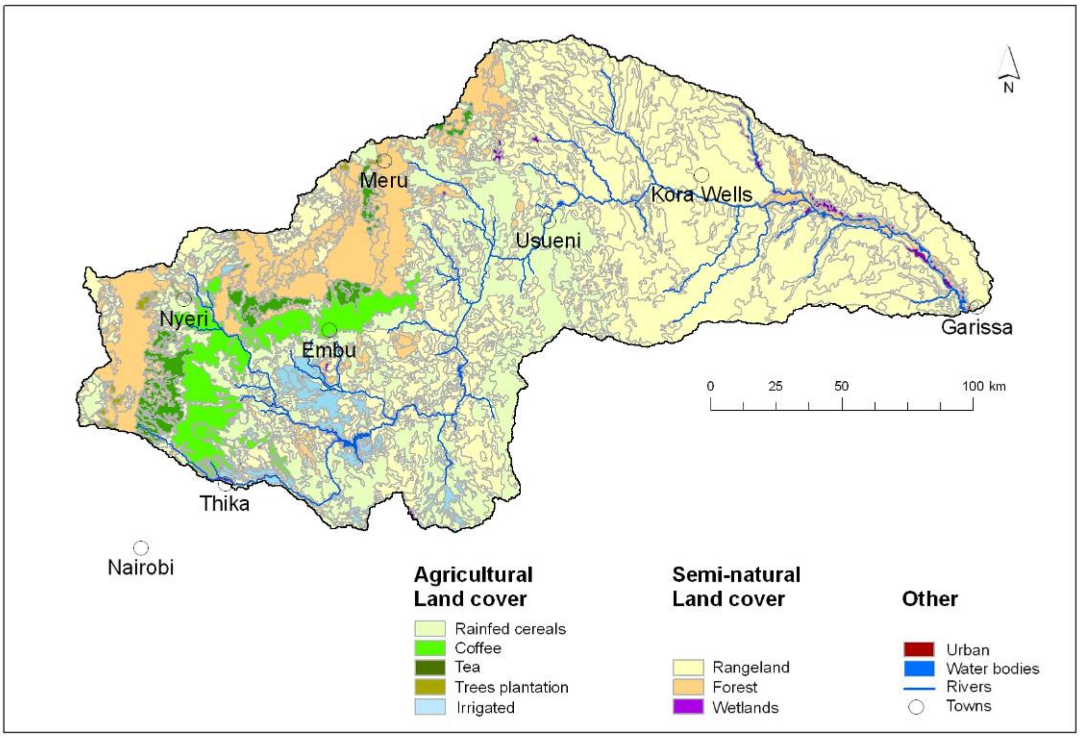


Figure 9: Upper Tana, land use
(FAO 2000)

Figure 10: Maize grown on steep slopes without soil conservation measures
During land preparation and early growth, there is much less ground cover

2.3 Water users

Five main groups of downstream water users and potential buyers of water management services are identified:

- Kenya Electricity Generating Company (KenGen)
- Nairobi Water Company (NWC)
- Irrigation sector, both large enterprises and smallholders
- Ecosystems (represented e.g. by Kenya Wildlife Conservation Department)
- Insurers and re-insurers.

Relevant issues for potential buyers include:

1. Regulation of water flow, in particular insurance against dry spells;
2. Sediment load, especially from the immediate catchments of the reservoirs which are suffering heavy siltation;
3. Control of flooding with its attendant damage to infrastructure and risks to public heath and safety;
4. Total water availability, both upstream and downstream;
5. Water quality.

2.4 Legal, institutional and operational framework

If it is to be successful, Green Water Credits must be an integral part of water management in Kenya. The current water-sector reform, which espouses the principles of integrated water resource management (Box 1) and assigns an economic value to water, is a window of opportunity.

The Ministry of Agriculture, and the Ministry of Water & Irrigation are mandated to ensure effective use and management of land and water resources; their various specialist agencies have key roles in technical assessments, capacity building and extension. Following the Water Act 2002, the legal framework has been re-cast through the institution of a Water Resources Management Authority (WRMA) responsible for the implementation of the Act through Water Rules and Norms (WRMA 2007). Under the WRMA, the Tana River Basin Authority is responsible for investment and development projects in the basin which are encompassed by the Tana River Catchment Management Strategy (WRMA 2006). Within the Catchment Management Strategy, Green Water Credits may provide a mechanism for addressing land degradation and the management of farmland as a water source, reservoir and regulator.

3 Water supply

3.1 Water management at source

Prima facie, there is a trade off between *green* and *blue* water resources: between direct runoff to streams and water infiltrating into the soil. However, a win-win situation may be achieved by appropriate soil use and management.

Runoff erodes the soil, carrying it to the rivers, and floodwater exacerbates bank erosion that further increases the sediment load and fills reservoirs with mud. Apart from the damage caused to life and property, floodwaters are hardly accessible for use downstream. By contrast, rainwater that infiltrates the soil may be either used by crops or drain deeply to recharge groundwater and stream base flow. Some soil water may also evaporate unproductively from the soil surface; cutting this unproductive loss by in-field water management can actually increase *green* and *blue* water flows.

The biophysical assessment (Report 3, Kauffman and others 2007) quantifies the effects of various management options. It demonstrates the links between land use and management in the catchment and water supply and water quality downstream. The following baseline information is used as input to models of in-field water balance and basin hydrology, or to validate the model outputs:

- *Terrain and river network*, from the SRTM digital elevation model (NASA 2006). The catchment is characterized by steep gradients, and a range of elevation from over 3000 m in the Aberdares and Mount Kenya to about 200m at Garissa;
- *Agro-climatic zones*: There is strong correlation between climate and land use, and between relief and climate - high elevations are characterised by high rainfall and a soil water surplus, and low elevations by low rainfall and soil water deficit (Jaetzold and Schmidt 1983);
- *Meteorological data* from first-category stations and the CRU dataset (Mitchell and others 2004). The dry year 1996 and the wet year 1997 are used as reference for field and basin assessments;
- *Land cover* and cultivated land abstracted from the AfriCover dataset, effective scale 1:100 000 (FAO 2000);
- *Soil types and soil water data*, abstracted from the updated KenSOTER database, effective scale 1:250 000 (Batjes and Gicheru 2004);
- *River discharge and basin hydrology:* The most complete dataset, for the period 1960 – 1995 is maintained by the University of Nairobi (Govt Kenya 2005);
- *Soil and water conservation standards:* erosion risk and field-measured erosion data for major land uses are taken from the World Overview of Conservation Approaches and Technologies (WOCAT 2007) and various national studies.

In consultation with local experts, three low-cost green water management practices were selected for scenario analysis: grassed contour strips (Figure 11), mulch (Figure 12) and tied ridges (Figure 13). The potential effects of each practice on runoff, soil erosion, infiltration and evaporation are based on field measurements within and outside Kenya.

Figure 11: Contour strip of Napier grass
The strip of grass is a permeable barrier to overland flow; it intercepts sediment and allows time for water to infiltrate

Figure 12: Mulch
Mulch intercepts raindrops, preventing splash erosion and allowing clear water to infiltrate the soil. It also insulates the soil surface from wind and sun, reducing evaporation and sheltering earthworms that create a permeable topsoil, and it decomposes to humus that stabilises soil structure.

Figure 13: Tied ridges
Cross-ties between cultivation ridges create basins that hold water on the surface until it can infiltrate

Various hydrological and crop models were evaluated and the following chosen:

- Soil and Water Assessment Tool (SWAT, EPA 2007) for basin-scale analysis of the impact of land management practices. SWAT integrates the effects of rainfall, evaporative demand, terrain, soil type and land cover to assess runoff, groundwater recharge, stream flow, soil erosion and sediment transport;
- Water Evaluation and Planning Tool (WEAP, Yates and others 2005) for water allocation, infrastructure, and economic evaluation at basin scale;
- World Food Studies (WOFOST, Boogaard and others 1998) to estimate water balance according to climate, crop and soil, and management conditions at the field scale.

For the proof of concept, the hydrological effects of green water management are calculated in with- and without-intervention scenarios at field and river-basin level for a dry year (1996) and a wet year (1997).

3.2 Water resources scenarios

The extent of the *water towers* (Figure 17) and the sources of sediment entering the streams (Figure 18) are defined by SWAT modelling – taking account of rainfall, evaporative demand, soils, land use and management. Indicators are summarised in Figure 19 and Table 4.

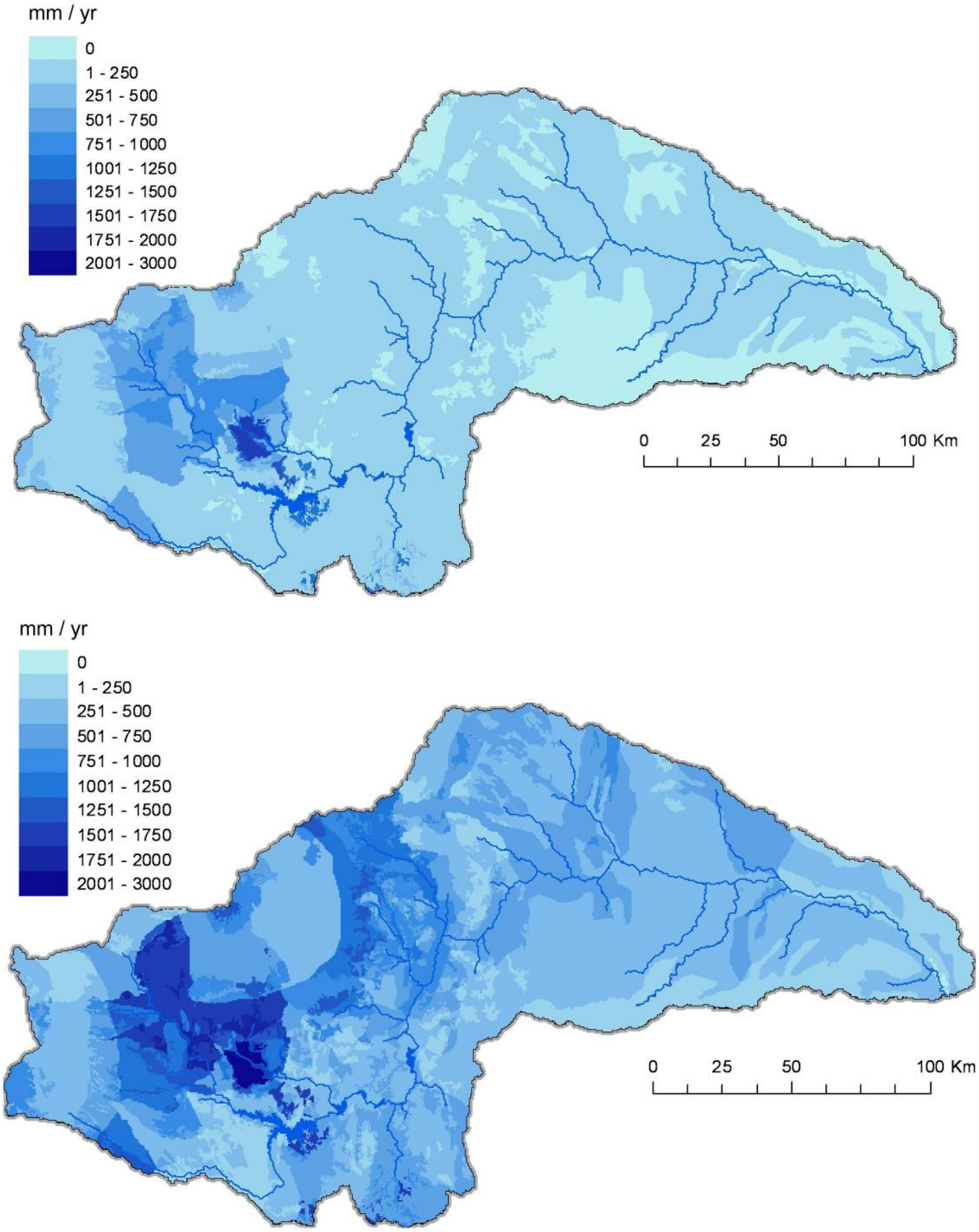


Figure 14: Upper Tana – *Blue* water flows in a dry year, 1996 (above) and a wet year, 1997 (below)

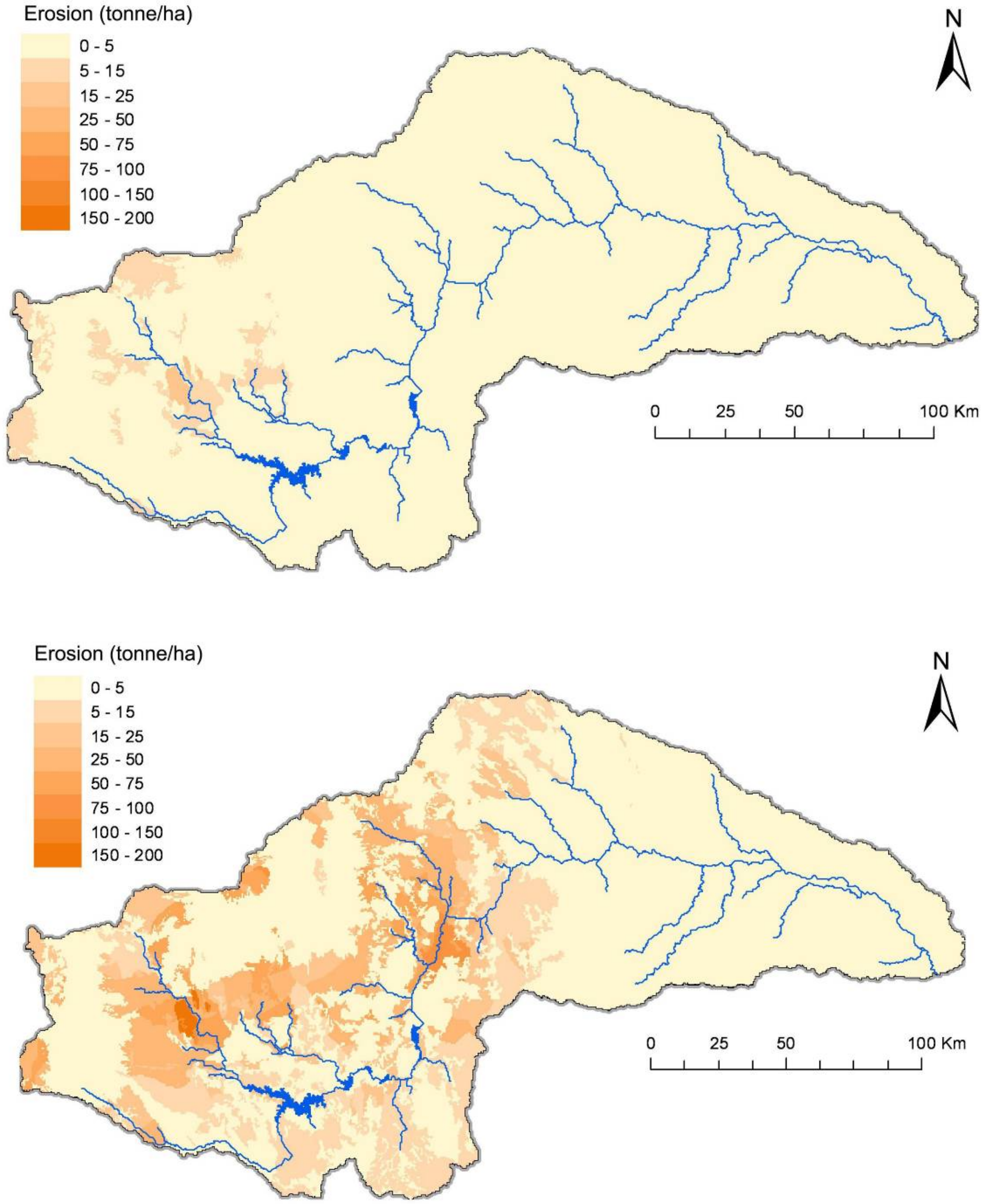


Figure 15: Upper Tana - Soil erosion for a dry year, 1996 (above) and a wet year, 1997 (below)

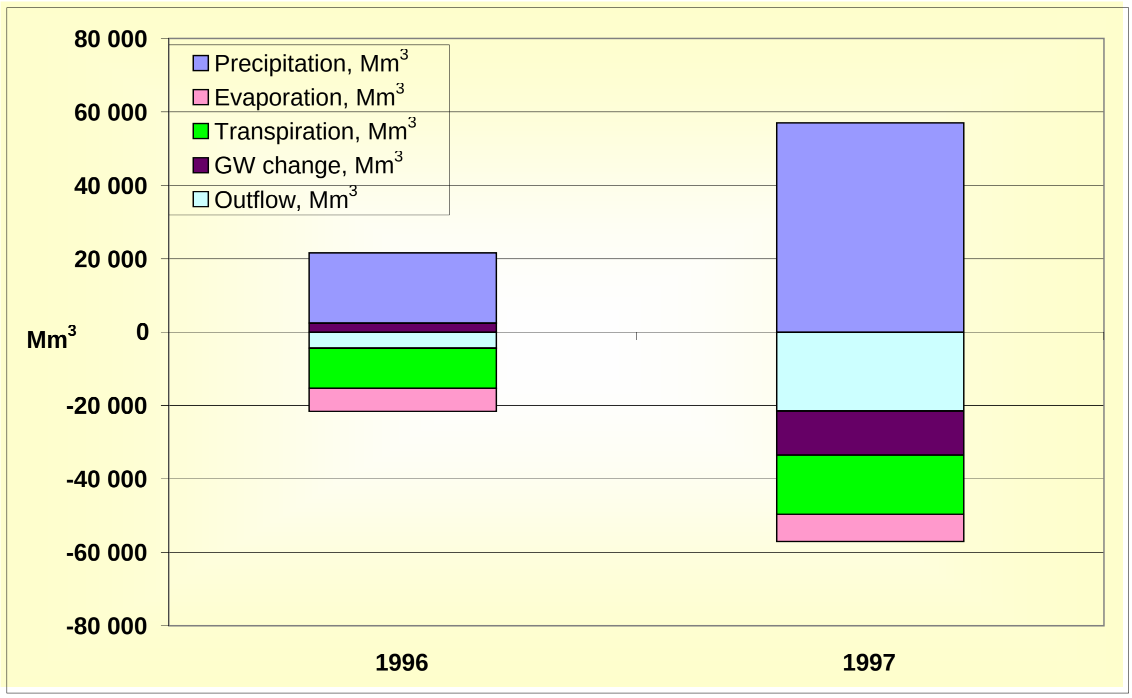


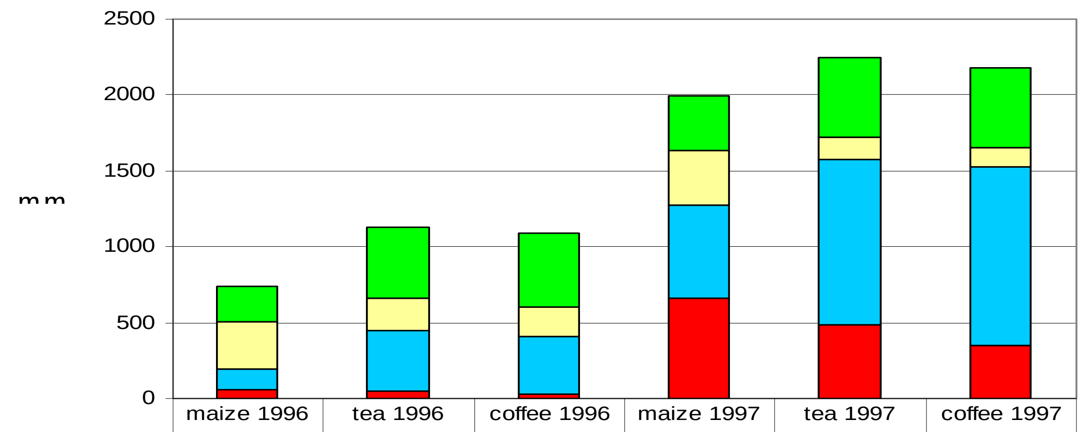
Figure 16: Basin water balance for a dry year (1996) and wet year (1997)

Table 4: Upper Tana catchment, indicators

	1996	*1997*
Indicators		
Inflow, Masinga (million m^3)	3 242	7 152
Sediment input, Masinga (tonnes)	953 300	5 281 000
Outflow, Garissa (million m^3)	4 358	21 482
Crop Transpiration (mm)	396	510
Evaporation from soil surface (mm)	205	224
Groundwater Recharge (mm)	169	745
Groundwater Recharge (m^3/ha)	1 695	7 445
Soil loss (tonne/ha)	1	14
Basin water balance		
Area (km^2)	32 741	32 741
Rainfall (million m^3)	19 126	57 023
Transpiration (million m^3)	10 950	16 141
Evaporation from soil (million m^3)	6 289	7 375
Outflow (million m^3)	4 358	21 482
Groundwater change (million m^3)	-2 471	12 024
Maize		
Area (km^2)	2 203	2 203
Rainfall (mm)[1]	688	2 014
Transpiration (mm)	233	361
Evaporation from soil surface (mm)	312	354
Groundwater recharge (mm)	134	614
Runoff (mm)	59	663
Soil loss (tonne/ha)	3	34
Tea		
Area (km^2)	838	838
Rainfall (mm)[1]	1 057	2 291
Transpiration (mm)	475	524
Evaporation from soil surface (mm)	214	140
Groundwater recharge (mm)	396	1 092
Runoff (mm)	47	487
Soil loss (tonne/ha)	0	7
Coffee		
Area (km^2)	1 739	1 739
Rainfall (mm)[1]	1 017	2 225
Transpiration (mm)	481	521
Evaporation from soil surface (mm)	197	135
Groundwater recharge (mm)	377	1 176
Runoff (mm)	31	347
Soil Loss (tonne/ha)	4	58

[1] Rainfall values are the mean for the areas under which the crop is grown, so vary from crop to crop

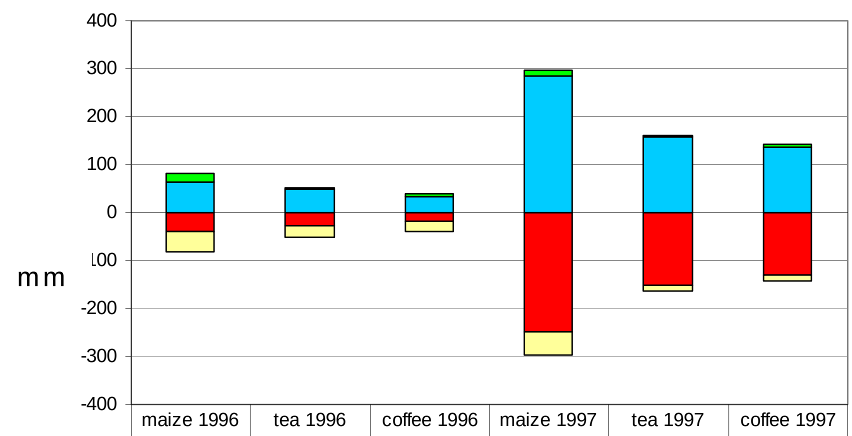
Field water balances of the three main crops are shown in Figure 17. Runoff and groundwater recharge are much greater in wet years than in the dry years. In dry years, unproductive evaporation from the soil surface is a significant proportion of water use, especially under maize which is grown mainly in the drier areas.



	maize 1996	tea 1996	coffee 1996	maize 1997	tea 1997	coffee 1997
Transpiration	233	475	481	361	524	521
Evaporation	312	214	197	354	140	135
Groundwater	134	396	377	614	1092	1176
Runoff	59	47	31	663	487	347

Figure 17: Baseline crop water balances in a dry (1996) and a wet (1997) year

Green water management significantly enhances rainwater infiltration and reduces runoff and, therefore, soil erosion and flooding. Figure 18 depicts the effects of mulch - which yields an absolute increase usable water resources by reducing unproductive evaporation from the soil surface.



	maize 1996	tea 1996	coffee 1996	maize 1997	tea 1997	coffee 1997
Transpiration	16	4	6	11	3	4
Evaporation	-42	-22	-20	-50	-14	-13
Groundwater	65	47	34	285	159	137
Runoff	-39	-28	-19	-247	-150	-129

Figure 18: Changes in crop water balances with mulch, compared with the baseline, for a dry year (1996) and a wet year (1997)

Table 5 summarises the effects of green water management over all the whole area currently occupied by rain-fed crops.

Table 5: Change compared to baseline for the different soil and water management scenarios

	Contour strips		*Mulch*		*Tied ridges*	
	1996	*1997*	*1996*	*1997*	*1996*	*1997*
Indicators						
Inflow, Masinga (million m^3)	28	-79	155	-104	88	-224
Sediment input Mas. (tonnes)	-307 100	-1 188 000	-609 900	-2 138 000	-686 900	-2 515 000
Transpiration (mm)	0	0	4	3	0	0
Evaporation (mm)	0	1	-10	-11	1	2
Groundwater recharge (mm)	8	44	21	99	19	122
Groundwater recharge (m^3/ha)	81	440	209	992	190	1215
Soil loss (tonne/ha)	-1	-5	-1	-6	-1	-7
Basin balance						
Area (km^2)	0	0	0	0	0	0
Rainfall (million m^3)	0	0	0	0	0	0
Transpiration (million m^3)	7	2	118	91	9	3
Evaporation (million m^3)	13	31	-283	-333	32	73
Outflow (million m^3)	25	-281	148	-397	60	-842
Groundwater (million Mm^3)	-45	248	17	640	-101	766
Maize						
Transpiration (mm)	1	0	16	11	1	0
Evaporation (mm)	2	4	-42	-50	3	6
Groundwater recharge (mm)	34	188	65	285	55	347
Runoff (mm)	-32	-195	-39	-247	-51	-357
Soil loss (tonne/ha)	-2	-17	-2	-17	-2	-18
Tea						
Transpiration (mm)	0	0	4	3	0	0
Evaporation (mm)	0	0	-22	-14	0	0
Groundwater recharge (mm)	23	103	47	159	31	149
Runoff (mm)	-21	-105	-28	-150	-29	-151
Soil loss (tonne/ha)	0	-3	0	-3	0	-2
Coffee						
Transpiration (mm)	0	0	6	4	0	0
Evaporation (mm)	0	0	-20	-13	0	0
Groundwater recharge (mm)	16	91	34	137	21	128
Runoff (mm)	-15	-93	-19	-129	-20	-130
Soil loss (tonne/ha)	-3	-28	-3	-28	-3	-21

1996 was a dry year and 1997 a wet year

Compared with the present, adoption of green water management will:

- Cut runoff by 22 per cent in dry years and 66 per cent in wet years; even the cheapest measure has a big impact (Figure 19). An immediate benefit will be to abate siltation; for the Masinga reservoir, siltation will be cut by a quarter in dry years and three quarters in wet years (a cut of 307 000 and 2 515 000 tonnes/year, respectively). This means a longer lifetime for the reservoirs; (Wanyonyi (2002) estimated that siltation reduced the storage capacity of the Masinga reservoir by 10-14 per cent over the period 1981-2000; WWAP (2006) put the figure at 29 per cent. The life of hydro-power turbines will also be extended;
- Increase inflow to reservoirs *in dry years* (Figure 20). For 1996, mulching would have increased inflow to the Masinga by 155 million m^3;
- Increase groundwater recharge by 4-57 per cent (16-160 mm), a potential *blue* water gain of 160-1600 m^3/ha/year in dry and wet years, respectively, which feeds through to improved river base flow;
- Reduce unproductive evaporation from the soil surface. Mulch, in particular, is effective in both in dry and wet years; potentially this will yield a 300 million m^3 increase in *blue* water flow by cutting evaporation under tea and coffee by about 20 mm year (200 m^3/ha); and by 40 to 50 mm per year (400 to 500 m^3/ha) under maize.
- There is also potential for big saving water savings in irrigation schemes.

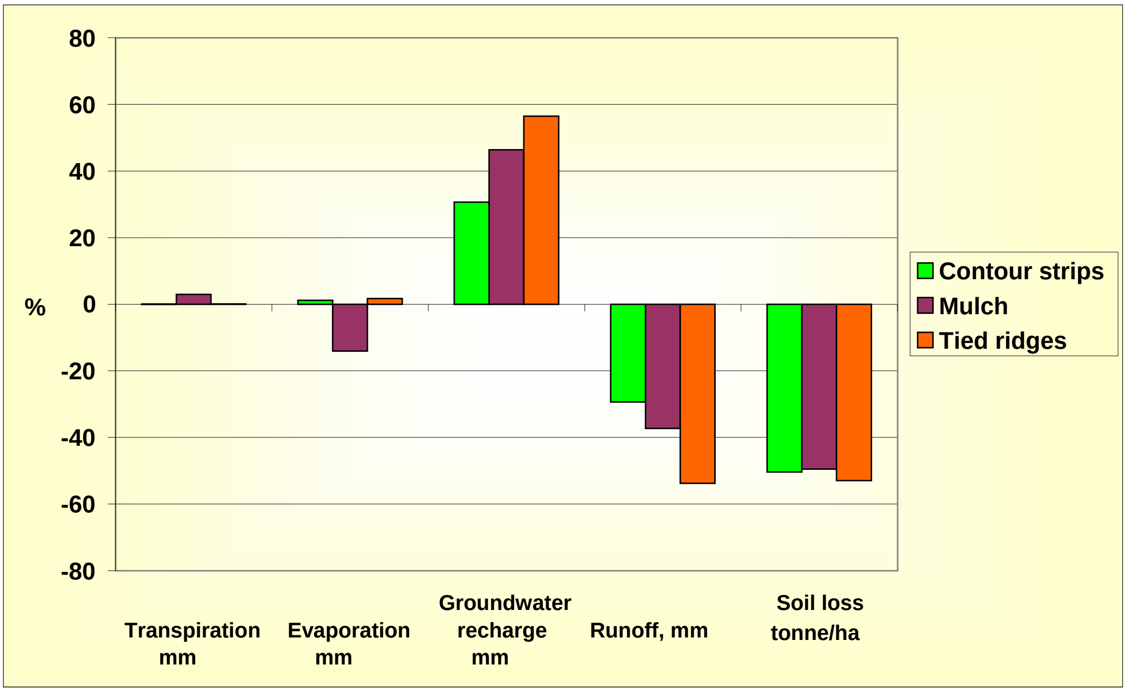
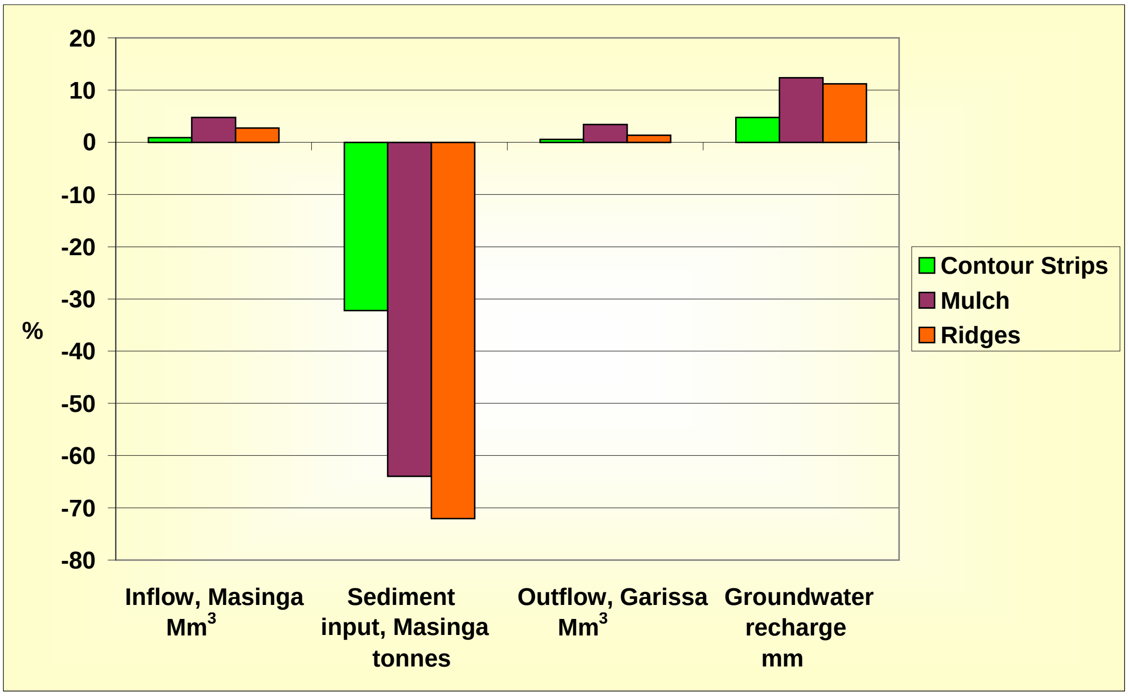


Figure 19: Effects of green water management practices under maize, 1997



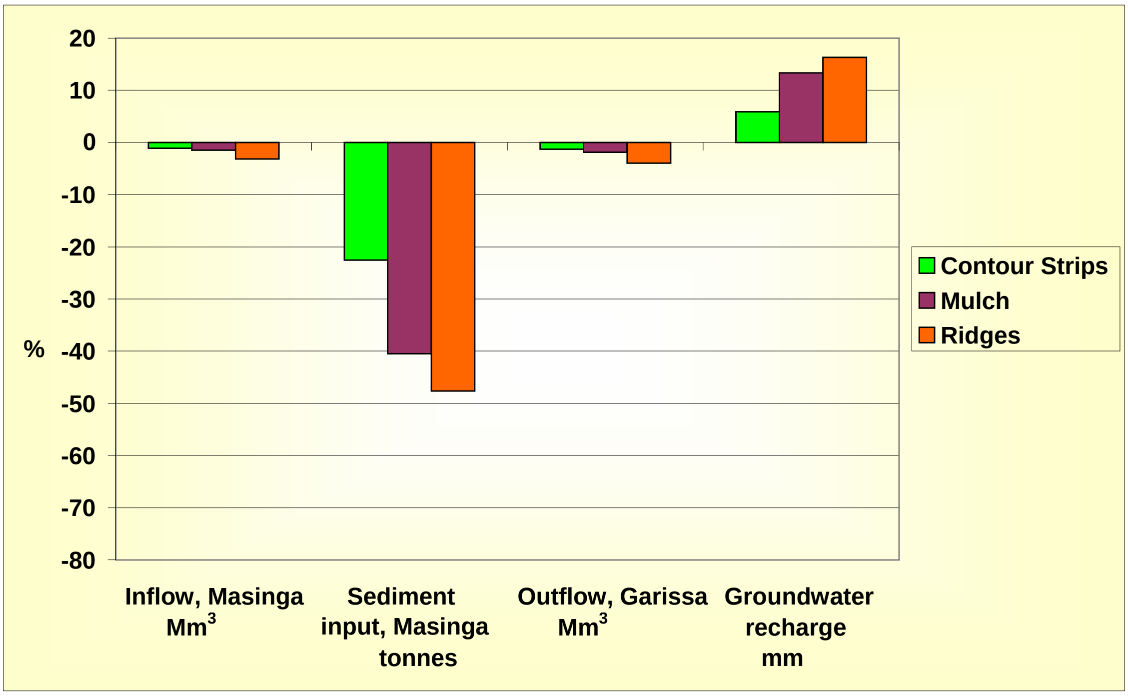


Figure 20: Hydrological effects of SWC in a dry year (1996, top) and a wet year (1997, below)

3.3 Patterns of adoption of best management practice

The above data assume adoption of green water management across the whole area presently occupied by rain-fed crops. This will not happen; it is important to identify priority areas for the introduction of Green Water Credits. The effects of partial uptake are not directly proportional to the areas involved but depend on location. The effects will be greater in areas of higher rainfall, and modified by terrain and soils; Figures 14 and 15 delineate the areas responsible for most of the *blue* water flows and sediment, respectively.

Within areas subject to soil erosion, green water management on land close to rivers will have the greatest effect on sediment loads because a buffer zone will intercept sediment that is moving from upslope. This may be illustrated by a simple model, assuming:

- Fields of 25 m x 25m
- Area of 50 ha (500 x 1000 m = 20 x 40 fields), with river through the middle
- Soil erosion of 30 tonne/ha/yr without interventions
- Green Water Credits impacts:
    - erosion reduced to 5 tonne/ha/yr
    - down-slope sediment transport of 75 per cent from upstream fields.

The model assumes that all fields are the same. Actually, fields close to streams have gentler slopes, less-erodible soils, and thicker vegetation so they generate less sediment.

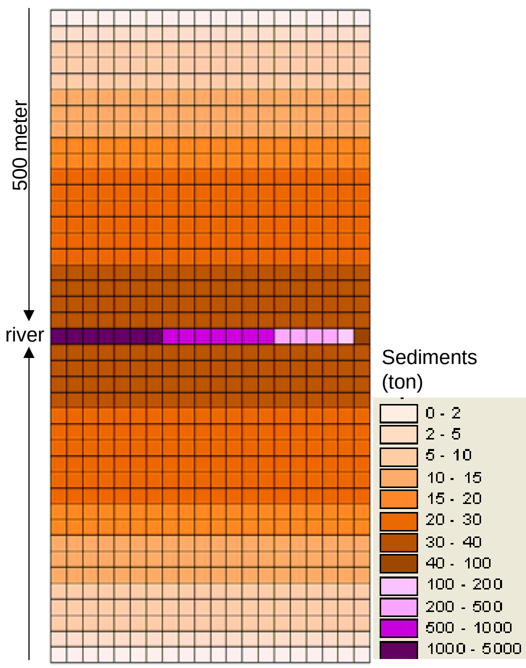


Figure 21: Sediment transport without green water management

Figure 21 illustrates the business-as-usual scenario: sediment yield is 1500 tonnes/yr. Figure 22 illustrates 20 per cent uptake of Green Water Credits at random locations: sediment transfer to the river is 812 tonnes/yr. Figure 23 shows 20 per cent uptake on adjacent fields bordering the river: sediment transfer to the river is 405 tonnes/yr.

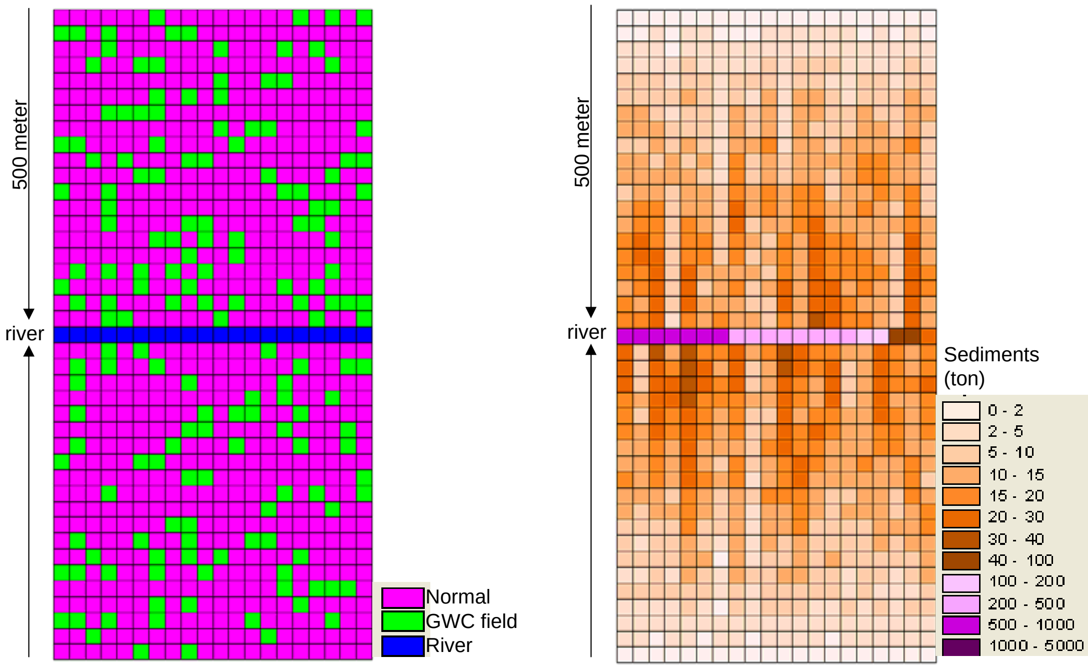


Figure 22: Sediment transport with random 20 per cent implementation of green water management

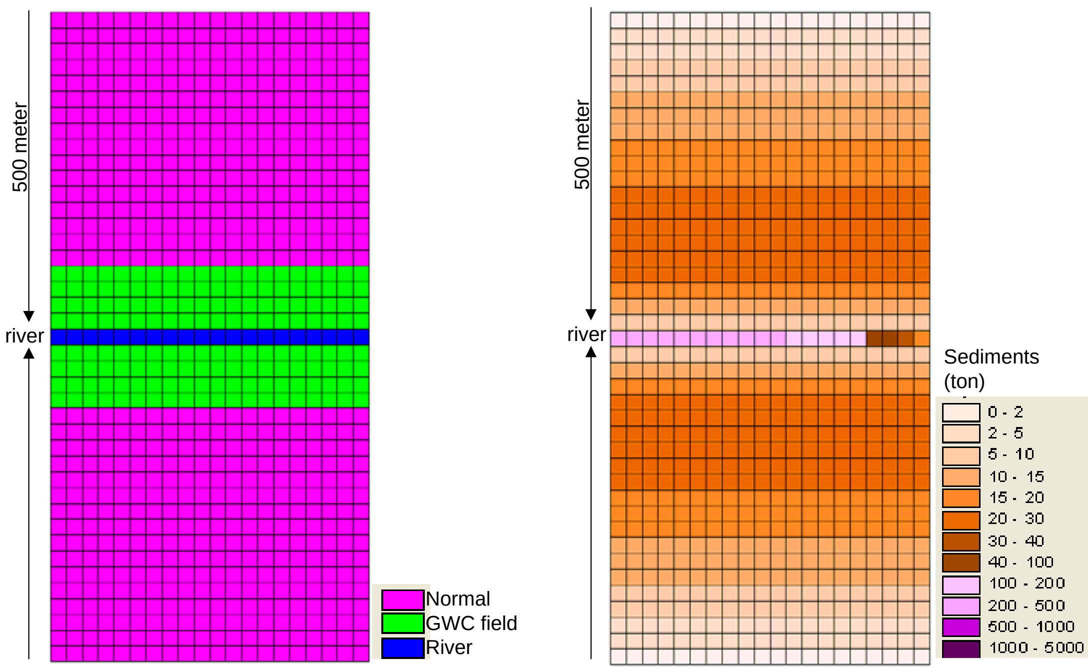


Figure 23: Sediment transport with 20 per cent implementation of green water management, all next to the river

Figure 23 shows the relationship between the proportion of fields where conservation measures are implemented and the total sediment load in the river. It is clear that even a partial uptake of Green Water Credits will make a significant impact on sediment loads in the streams and, therefore, on reservoir siltation.

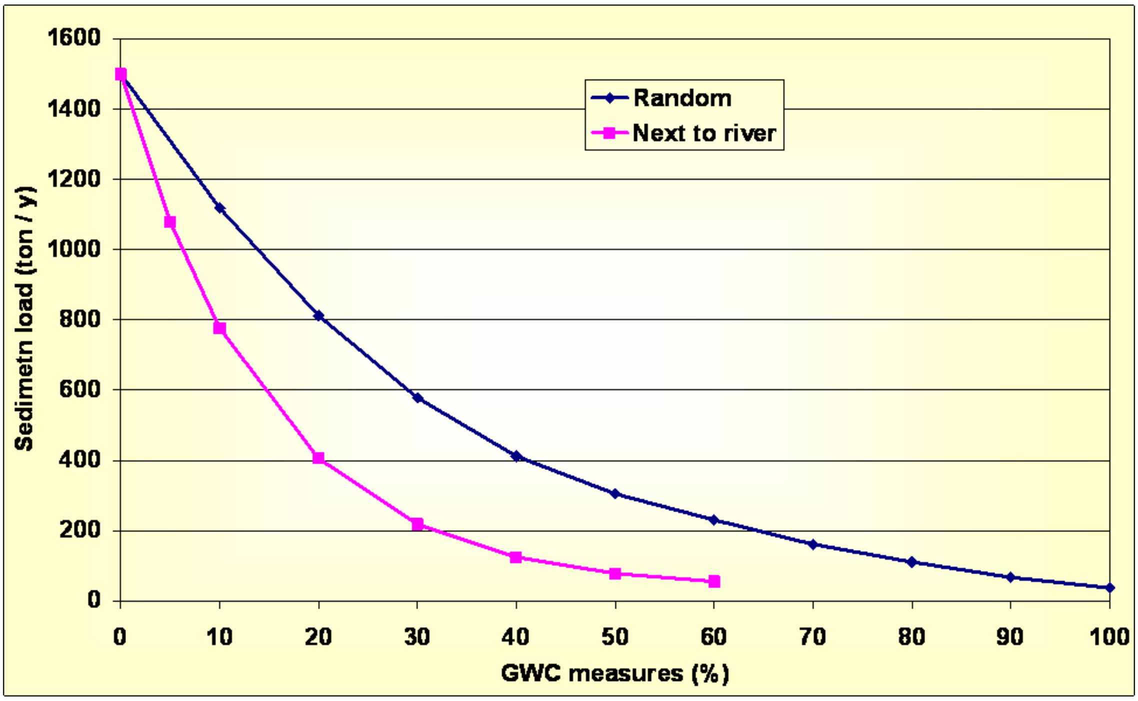


Figure 24: Relation between uptake of Green Water Credits, location of uptake, and sediment load

4 Water demand

4.1 Water reform

Radical reform of the water sector was instituted by the 2002 *Water Act* and the *National Water Resource Management Strategy* 2006 – 2008 (Govt Kenya 2006a). The reforms espouse the principles of integrated water management, decentralization of management to the basin level, assignment of an economic value to water, and the introduction of user charges and permits. These reforms set the stage for Green Water Credits. The draft *Water Resource Management Rules and Forms* (WRMA 2006) recognize categories of water users according to their impact on water resources - users are to be charged according to the type of activity and their level of abstraction (Table 6). The introduction of Green Water Credits would mean a broader basis for water charges and credits, according to removals and contributions to the catchment water bank.

Table 6: Draft Water Rules and Norms - indicative water tariffs

User	Criteria	Rates
Domestic, public and livestock	Domestic, public, and livestock purposes, up to the limit allocated	50 cents/m^3
Hydropower generation	Energy generated	15 cents/ kw-hr
Irrigation/ agriculture / fish farming	Up to 500 m^3/day	50 cents/m^3
	Any water in excess of 500 m^3/day	1Ksh/m^3
Commercial / industrial	Up to 300 m^3/day	50 cents/m^3
	Any water in excess of 300 m^3/day	1Ksh/m^3
Bottled drinking water		1Ksh/m^3
Effluent discharge		1Ksh/m^3

Catchment Management Strategies are now being developed by the WRMA. These combined water resources and business plans provide a practical entry point for the information generated by the Green Water Credits process.

4.2 Water Evaluation and Planning tool (WEAP)

The Green Water Credits process examines development options in terms of both their hydrological effects and the cost per unit of water. The first task is to assess water resources and the feasibility of the various green water management practices - and their effects on *green* and *blue* water yields, regulation of river and groundwater flow, and abatement of soil erosion and siltation. Quantitative information about the effects of green water management is derived from basin management simulations, calibrated and validated by in-field measurements (Section 3).

Building on this foundation, the process moves on to negotiations on two fronts: 1) to agree upon the optimum allocation of water between various competing demands, and 2) the land use and management needed to secure the desired water delivery outcome and agreement upon a fair price for this service.

Reallocation of water resources must take account of constraints and boundary conditions: for instance, water allocations for hydro-power are not negotiable because Kenya depends on this power, and there are political limits to the introduction of water user charges that aim at cost recovery. Assessment of the upstream–downstream links for different water allocation scenarios requires a water management model that can integrate water supply, resulting water sufficiency or un-met demand, as well as costs and benefits. The Water Evaluation and Planning tool (WEAP) is an uncomplicated tool designed for this job (Figure 25).

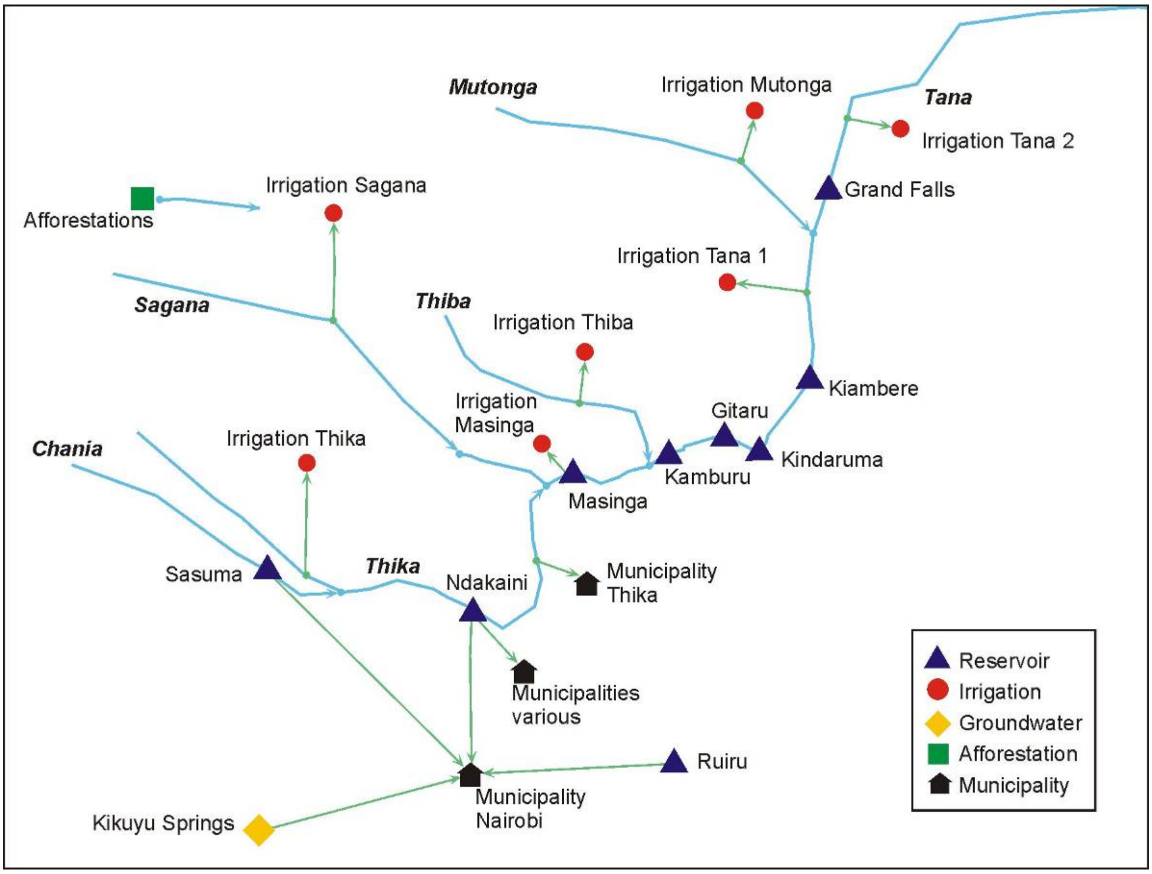


Figure 25: Upper Tana - WEAP framework of water users and priorities

WEAP integrates information on water availability with information on water demands (irrigation, urban water users, hydro-power, and environmental flows). This enables an analysis of the costs and benefits of various options to match supply with demands; allocation can then be made on the basis of agreed priorities. Data for extreme dry and wet years are analysed to assess vulnerabilities, potential mitigation options, and coping capacity.

4.3 Main water users

4.3.1 Hydro-power

Hydro-power is strategically critical to Kenya; it provides 50 to 80 per cent of the country's electricity, depending on rainfall. Eighty per cent of hydro-power is generated from the Tana. Demand increased by 9 per cent annually during 1960-1979, 7 per cent during the 1980s, 5 per cent during the 1990s, and is now surging again. From 2004 to 2005 consumption rose by 6.8 per cent (Govt Kenya 2006b) and a tripling of demand over the next 20 years is forecast - rising from 885 MW in 2005 to 2397 MW in 2025/26 (KPLC 2006). KenGen has great difficulty meeting this demand. During the 1999-2000 drought, hydro-power generation fell by 40 per cent (Mogaka and others 2006); the cost to the hydro-power industry was $US 68 millions per month; the loss of industrial production, $US 1.4 billion. Kenya had to turn to thermal power generation from imported oil and increase its energy imports from Uganda - which in 2003 stood at 190 MW, though cut back to 28 MW by 2005.

Siltation of the reservoirs is a big issue; it reduces their regulating capacity and damages the turbines. There are various estimates of the rate of siltation; in the case of the Masinga reservoir, WWAP (2006) reckons that, in the 20 years up to 2002, the reservoir lost some 460 million m^3 or 29 per cent of its storage capacity – though this figure is disputed by KenGen pending confirmation of the water level from which the measurements were made. Figure 29 depicts the increase in hydro-power production that may be achieved through a 50 per cent reduction of soil erosion and siltation by green water management in the catchment. This is conservative in the light of the 80 per cent reduction achieved at the Tungabhadra reservoir in India, and an average reduction of erosion of 76 per cent for all examples of SWC measures in Kenya recorded by WOCAT (Wanyonyi 2002).

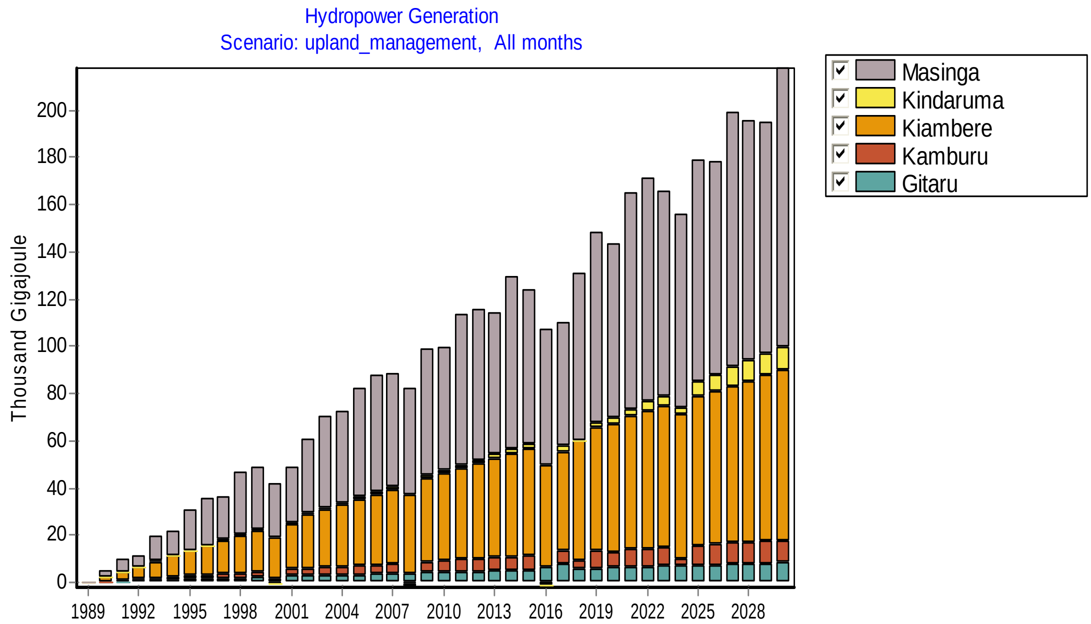


Figure 26: Increase in hydro-power production for a green-water-management scenario

Units of power translate directly into equivalent oil imports needed to generate the same amount of electricity: an additional 100 Gigajoules (generated in year 2010 in Figure 26) is equivalent to the import of 51 000 barrels of oil (NUON pers. comm.) or $US 4.44 million at the spot price of fuel oil (29 July 2007 =$US 87/barrel). Further financial benefits will accrue from improved stream flows. The additional 155 million m^3 stream flow that would be generated in a dry year by applying mulch to farmland (Table 4) would generate 460 Gigajoules, offering the possibility of holding off commissioning of the proposed Grand Falls dam, downstream of Kiambere.

4.3.2 Consumptive uses

Water demand from all sectors is set to increase dramatically. Figure 30 depicts a conservative scenario using the actual trend up to 2006, thereafter a 6 per cent annual increase is applied to municipal demand and a three per cent increase to irrigation.

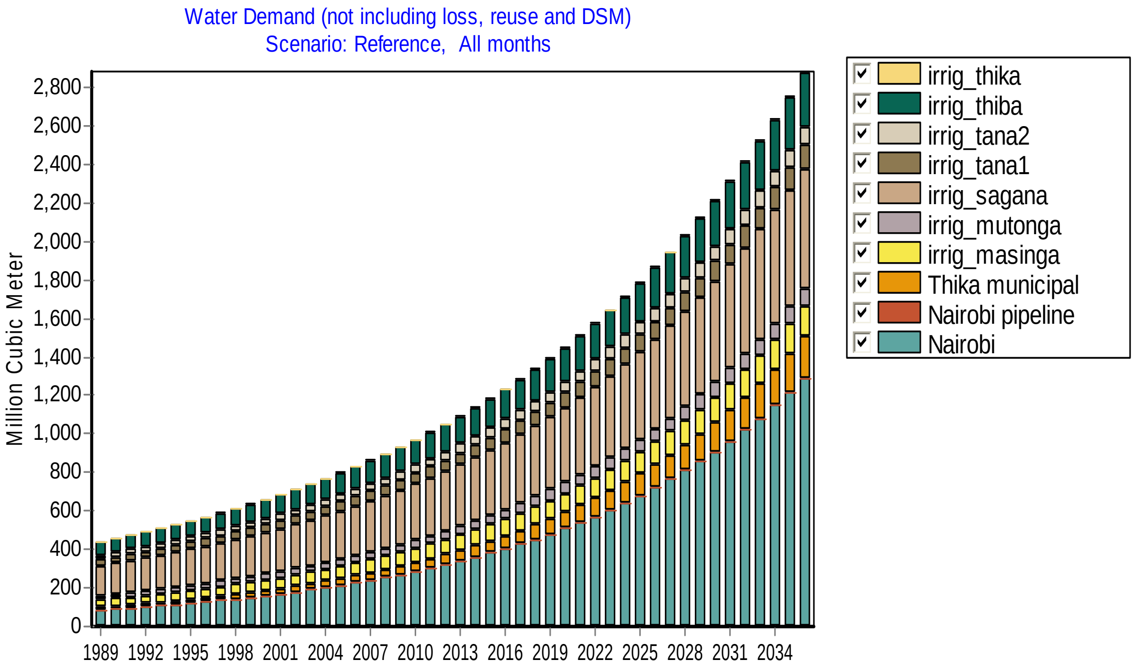


Figure 27: Water demand up to 2036

Municipal water supply

The Nairobi Water Company abstracts 70-80 per cent of its water from the Ndakaini reservoir in the Upper Tana. Municipal water demand stems from domestic and commercial requirements of 3 million residents. A 3-5 per cent annual increase in demand is projected, assuming that water consumption is constant at a nominal 70 m^3/person/year.

Nairobi Water is unable to meet present demand; for example, during the June - September 2006 dry season, 456 000 m^3/day was abstracted (384 000 m^3/day from Ndakaini) but demand was 570 000 m^3/day, a shortfall of 20 per cent. Under a business-as-usual scenario, Nairobi Water faces increasing unmet demand; it needs increased water flows and/or drastic demand-management measures. Various options have been explored, including tapping the Tana water north of Ndakaini but this is opposed by other water users as it would reduce water flow for their operations.

Siltation is also a significant cost. Between 2003-6, $50 000 annually was spent digging silt out of the Sasumua reservoirs, and $50 000 a year to counteract sedimentation throughout its catchments. Water purification is another big cost.

While Nairobi Water can be expected to be a major participant in Green Water Credits, its ability to pay may be an issue. The Draft Rules set a tariff of 0.50 Ksh/ m^3 for abstraction and 1 Ksh/m^3 for discharging effluent. Water prices are presently fixed and the company may be unable to meet even the presently proposed water and effluent charges from current income.

Irrigation

By far the greatest consumptive use of water is for irrigation. Water is abstracted from the Tana by large commercial growers (Del Monte, Kakuzi), public schemes (Mwea, Bura, Hola), community-based smallholder schemes (Yatta canal scheme) and, often illegally, by an unknown number of commercial enterprises and smallholders. Supply is far below the demand; the 68 700 hectares currently under irrigation represent only a third of irrigable land and all irrigators complain that they cannot get enough water.

Figure 28 shows the increase in irrigation demand from the present irrigated area under a climate-change scenario, assuming a 20 per cent decrease in drainage and a 10 per cent increase in evaporative demand driven by higher temperatures.

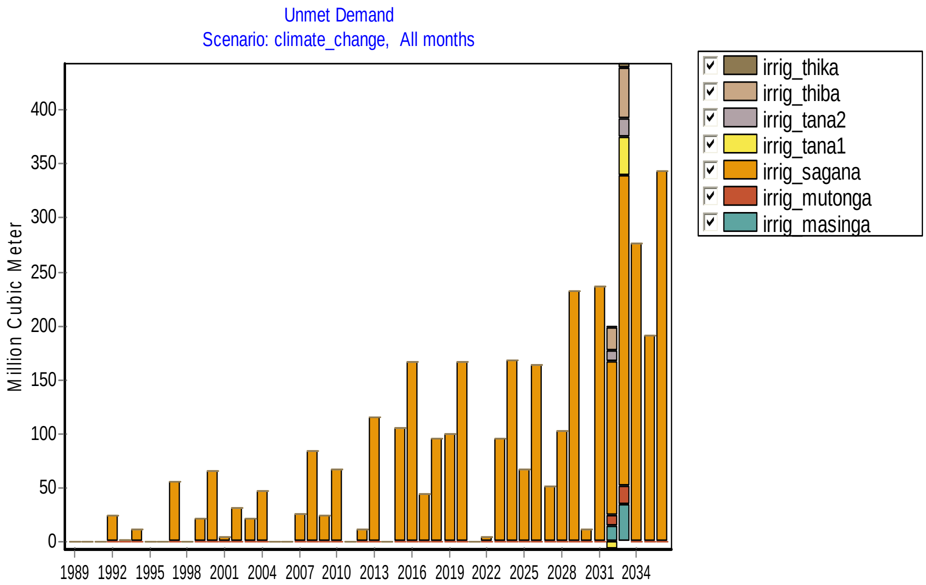


Figure 28: Un-met demands from irrigation under a climate-change scenario

The importance of crop choice and water management determining water demand may be illustrated by an extreme case of substitution of irrigated rice by rain-fed maize. The use of water by the rice crop, compared with maize, will be 1289mm compared with 526mm in a dry year (1996) and 679mm in a wet year (1997). In round figures, the difference in crop water use is 700mm but water-use efficiency in irrigated rice is only about 20 per cent, so replacement of irrigated rice with rain-fed maize means a saving of 700 x 5 = 3 500mm of water. For the Mwea Irrigation Scheme (a total area of 12 000 ha) this comes to 120 million m^2 x 3.5m = 420 million m^3 , more than double the total water demand of Nairobi.

Ecosystems

Environmental goods and services are often undervalued in water allocation decisions; e.g. the cost-benefit analysis for the proposed Grand Falls dam took no account of environmental impacts although the incremental cost of building a new dam involved a median present cost of almost US$20 million (IUCN 2003).

Ecosystem services, like water regulation, carbon fixation and waste cycling, depend on catchment management. Full consideration of the costs of ecosystem degradation is essential to calculate economic returns on investments in green water management.

Some of these wider environmental values are easily perceived; for instance. Kenya's tourism receipts ($US 559 million in 2004, $US 709 million in 2005 – Govt Kenya 2006b) depend on environmental flows. The Tana Basin is not a tourist honey pot like the Serengeti but Protected Areas within the basin include: Tana River Primate National Reserve (169 km^2 on the upper delta); Arawale National Reserve (533 km^2 the banks of the Tana River); Mwea National Reserve (42 km^2 northwest of Kamburu Dam); Kora National Park; and a string of reserves comprising the Meru, Kora, Mwingi and Bisanadi conservation area, an important wildlife dispersal area for Meru National Park.

Curtailed environmental flows and interception of sediment damage the aquatic ecosystems along the Tana River and mangroves and reefs the river mouth (Abuodha and Kairo 2001). UNEP (2006) claims that sediment input to the Indian Ocean has been reduced by 50 per cent by construction of the Tana reservoirs.

There is a link between tourism receipts and environmental health but it may not be possible to isolate this effect to the extent needed to induce local payments for environmental services. Given the global significance of the wildlife and the mangrove and coral reef systems, one approach would be to define an international demand and seek support from organizations that already recognize and value the link between water resources management and ecosystem sustainability, for instance through an international debt-for-nature swap, whereby national debt is traded against guarantees of environmental protection.

4.3.3 Cost-benefit analysis of Green Water Credits scenarios

Financial comparisons have been made using the total gross annual revenues of the water sector. This is a crude indicator; the costs to obtain these benefits have not been included in the analysis, and the worth of urban water supply is surely underestimated because the price of water is currently fixed for social reasons.

Figure 29 shows the revenues of the water sector for a dry year (1996) and a wet year (1997). Annual revenues are not very different between the two years, mainly because the drought extended into 1997 and water supply during much of 1966 was provided by depleting the reservoirs (Figure 30). Averaged for the two years, the gross revenues are: hydro-power $US 101 million, irrigation 74 million, urban 7 million; a total of 182 million.

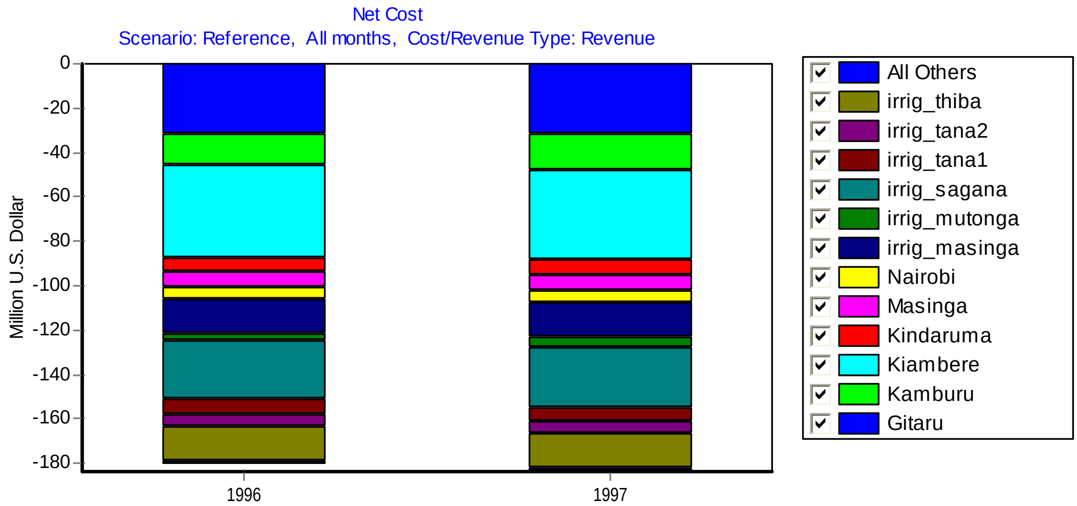


Figure 29: Annual revenues of all water users
Note that WEAP shows revenues as negative costs

Figure 30 shows WEAP outputs for reservoir storage and un-met water demand, respectively for the two years 1996-7.

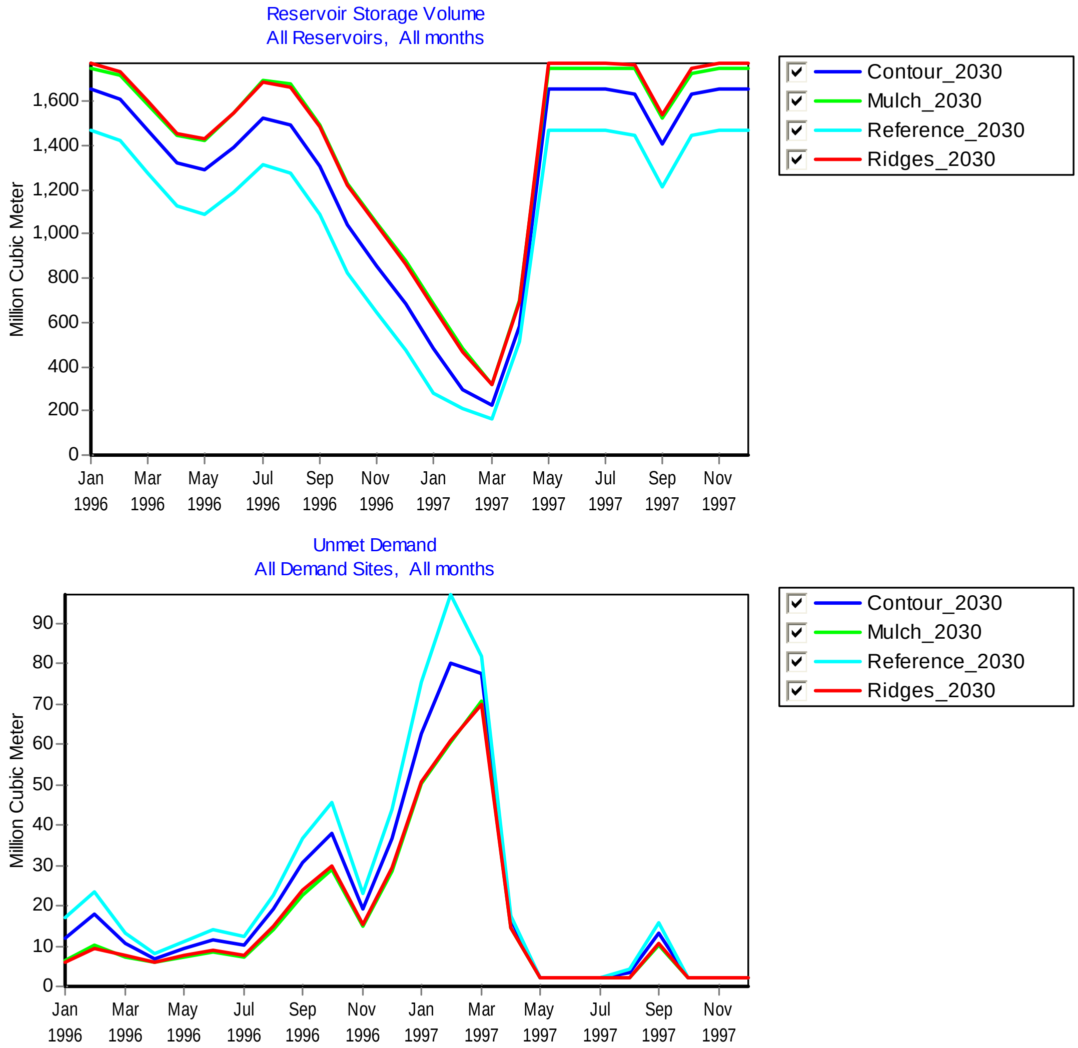


Figure 30: Reservoir storage volumes and un-met demand, 1996-7, for different green water management scenarios

Results from the SWAT basin model are used in WEAP to evaluate four scenarios:

- *Reference 2030:* loss of 40 per cent of reservoir capacity (20 per cent up till now and a further 20 per cent over the next 20 years)
- *Contour strips:* erosion reduced by 40 per cent, so total loss of capacity by 2030 is 32 per cent (20 + 20*(1-40%))
- *Mulch:* erosion reduced by 58 per cent, so total loss in 2030 is 28 per cent (20 + 20*(1-58%))
- *Tied ridges:* erosion reduced by 65 per cent, so total loss in 2030 is 27 per cent (20 + 20*(1-65%)).

The water benefits of the different green water management practices are estimated in financial terms using key indicators. In Table 7: the first column, *Reference* is the current situation; *Ref 2030* describes the situation in 2030 at constant prices if no conservation measures are taken - so the capacity of the reservoirs will be reduced by a further 20 per cent; the following three columns show the situation in 2030 with conservation measures in place, again assuming constant prices. With green water management, the negative financial trend will be reversed - mainly through reduced reservoir siltation but improved *blue* water flow due to improved groundwater recharge is also significant.

These projections are based on modelling; some of the input data are estimates but inaccuracies in the data and model assumptions are reflected in all scenarios, so that relative differences between scenarios are likely to be robust. Furthermore, the reference scenario is a projection of the linear trend of the last 20 years, whereas the drivers – the burgeoning demands of population and economic growth, unsustainable land use change, and climatic change, are increasing exponentially; the situation is almost certainly deteriorating at an accelerating rate.

Table 7: Financial evaluation of SWC measures

	Reference	*Ref 2030*	*Contour2030*	*Mulch2030*	*Ridges2030*
Un-met demand m^3 million	247	287	244	192	194
Revenues $ million	182	173	179	187	186
Hydro- power $ million	101	97	100	102	102
Irrigation $million	74	69	72	77	77
Urban $million	7	7	7	7	7
Hydro-power kWh million	2556	2453	2513	2580	2567

The above scenarios assume implementation of green water management across all cropland in the Upper Tana. This will not happen. Green Water Credits Report 3 (Kauffman and others 2007) also estimated the effects of partial adoption: as a rule of thumb, implementation of green water management over 20 per cent of the cultivated area may yield about 50 per cent of the gains in terms of reduced siltation of reservoirs; gains will be proportionately greater if areas adjacent to the waterways are targeted.

Table 8 provides an estimate of the costs of two scenarios: 1) applying green water management across the total area under coffee and maize; 2) adoption of green water management over only 20 per cent of the area. For contour strips, costs are derived from Shiferaw & Holden (2001) using the mean slope of cropland in the Upper Tana (7-10 per cent) and writing off the cost of construction ($8/ha) over 5 years, annual maintenance of $1.5/ha, and assuming that land taken up by the grass strips represents a total loss of production - *which is not necessarily the case*. For tied ridges, an annual cost of $50/ha is applied; for mulching, $25/ha.

Table 8: Annual costs of green water management

	Contour strips 100%	*Tied ridges 100%*	*Mulch 100%*	*Contour strips 20%*	*Tied ridges 20%*	*Mulch 20%*
Area, ha	394 200	394 200	394 200	78 800	78 800	78 800
Construction/ maintenance, $million	1.2	19.7	9.8	0.2	3.9	2.0
Area loss, $million	41.3	nil	nil	8.3	nil	nil
Total, $million	42.5	19.7	9.8	8.5	3.9	2.0

For the 100 per cent-adoption scenario, annual costs are in the range $US 10-42 million (or 2-20 million if the cost assigned to loss of area under grass strips is discounted); set against benefits of about $US 12 millions in terms of water revenues and 95 millions in terms of un-met demand. Under the 20 per cent-adoption scenario, annual costs will be in the range $US 2-8.5 million (or 0.2-3.9 discounting the area loss under grass strips); against annual water benefits of $US 3-7 million in terms of revenues and 48 millions in terms of un-met demand. Further big gains from flood mitigation and better crop yields have not been accounted.

These calculations are clouded by uncertainty about the current costs of green water management under local conditions, and the real cost of the area loss under grass strips - which produce valuable forage and mulch. However, it appears that the benefits of targeted conservation measures, in terms of water revenues alone, may exceed the total cost of green water management.

5 Land users' willingness to participate

5.1 Farmers' needs and constraints

Land users' willingness to engage in a Green Water Credits scheme, and the terms of engagement, have been assessed through an extensive literature review and through 10 focus groups in the target areas. Farmer's trade-offs, and private benefits from improved management practices were explored using a choice experiment (Table 9).

The need for soil and water conservation is well recognised. Farmers, government agencies and research institutions have a wealth of information and capacity but there is an implementation deficit. Farmers see sustainable land management as means to an end (*i.e.* production and income generation), rather than the end in itself. They are aware of their private benefits from sustainable land management but, also, demand a tangible gain from the land, capital and labour involved. They may not be aware of the downstream results of their activities.

5.2 Benefits and costs of SWC

Data on financial costs and benefits to farmers of soil and water conservation are equivocal:

- Benefits from conservation measures are highly specific. For instance, crop yields may be increased by terraces and green manure, but may be depressed by agro-forestry (Ekbom 2005);
- The farm-gate price of commodities and the fluctuation of prices affect the likelihood of adoption of conservation measures. The costs of constructing and maintaining mechanical structures are substantial - and often outweigh the returns. For instance, Shiferaw and Holden (2001) found negative net present values for most soil and water conservation measures under various crops; Pagiola (1996) calculated that, for semi-arid regions in Kenya, it takes 48 years to recover the cost of constructing soil conservation structures.

Farmers are engaged in various forms of green water management but lack of funds often means that they do not have enough seed, let alone other resources to invest in structures such as terraces. Informal group credit arrangements, like *merry-go-round*, have developed as safety nets but their impact is limited by the absolutely small amounts of money available. It is clear that incentives like Green Water Credits are needed to surmount these financial barriers. The farmers' private benefit in the shape of future improved crop production and sustainability is not enough.

Table 9: Summary of literature review and focus groups

Sources of information	*Results*
Modelling and livelihoods study *Theoretical models to understand linkages between private land use and externalities in the Tana Basin*	▪ Labour costs are a big part of the costs of green water management ▪ The costs of constructing and maintaining mechanical structures can be substantial ▪ Several studies have found that the private costs often outweigh the private benefits – in the absence of rewards such as Green Water Credits ▪ A supply-response curve for environmental services (in this case increased water supply) can be linked to biophysical data and model results
Focus groups *Objective: exploration of farmers' views on green water management, markets, organisational capacity and institutional settings in the Upper Tana* *Sample: Eight focus groups with rain-fed farmers and irrigators 4 agro-ecological zones*	▪ Knowledge of green water management has been built up through decades of implementation but there is a lot of room for improvement; mechanical structures are poorly maintained ▪ Farmers are aware of the potential, private, on-site benefits from green water management but demand tangible benefits for the substantial inputs required ▪ Many farmers participate in groups and associations (marketing, benevolent, cultural, etc.) ▪ To ensure farmers' ownership, the project design process should take into account their feasible suggestions about incentives and modes of payment ▪ Most farmers would prefer contracts of 3-5 years, the longer period being more preferred ▪ A group contract is preferred which, in turn, enforces the contract obligations upon its members ▪ A clear channel is required for periodic monitoring and feedback on progress of activities
Choice experiment *Objective: to determine the policy components (or attributes) that would make Green Water Credits more attractive (higher ratings) to farmers* *Sample size: 128 farmers in 4 agro-ecological areas*	Variables that tend to *increase* the rating by > 10%: ▪ Incentives: specifically - In-kind incentives - Tied cash - Access to revolving funds ▪ Ministry of Agriculture in charge of management ▪ Medium-to-long term benefits Variables that tend to *decrease* the rating by> 10%: ▪ Number of labour-days required ▪ Contract length (years) Variables with low predicted effect (<10%) ▪ Private managing institution ▪ Number of household members working regularly in the farm ▪ Current level of soil and water conservation ▪ Access to external markets ▪ Threshold level

5.3 Incentives

The Water Resources Management Authority (WRMA) is proposing a 5 per cent reduction in water charges for farmers adopting best practice. The impact on smallholders will be small but the proposal demonstrates a willingness to introduce market-based mechanisms. Incentives that may be considered under Green Water Credits are not limited to cash-for-conservation; they may extend to training in green water management practices, provision of implements and equipment, revolving funds for *soft* credit, long-term access to markets, regularisation and adjustment of land and water rights, and benefits to the community such as roads, schools and clinics. All of these have pros and cons. Some are gender-biased and it is difficult to enforce compliance with long-term contracts in the case of up-front, in-kind benefits.

Farmers' preferences, revealed in a choice experiment, are ranked: 1. In-kind benefits (provision of implements and equipment or community benefits such as roads and schools); 2. Tied cash, for instance school vouchers; 3. Credit from a revolving fund; 4. Cash payments. Underlying these preferences is a perception that up-front, in-kind benefits cannot be withdrawn.

Caveats expressed against incentives (not by the farmers), include: creation of expectations – and dashing these expectations in the case of early failure; a climate of dependence on cash payments; and difficulties of enforcing project requirements in the case of up-front, in-kind benefits.

5.4 Socio-economic and institutional constraints and opportunities

5.4.1 Poverty

Poverty is a severe constraint, both to implementation of green water management and the ability to pay for Green Water Credits.

Most farmers in the Upper Tana are smallholders and most farms sub-divided; farmers are usually poor, with limited access to markets and low prices for their produce. Linked to poverty is a preference for short-term benefits. In economics terms, this drives a high discount rate, at which the cost of green water management outweighs the financial benefits to the farmers.

There is also poverty in cities. If payments from downstream water users mean higher water charges, these higher water charges will further disadvantage already-vulnerable groups; many slum-dwellers already pay high charges for water purchased from vendors.

5.4.2 Farmers' groups

Cooperation among farmers and local organisations is essential to a functioning Green Water Credits mechanism:

1. The impacts of soil erosion and runoff are felt beyond the private plot; in many cases, the task of constructing and maintaining conservation measures is too demanding for one household;
2. It may be easier to make contracts with groups of neighbours than with every individual; extension services will be more efficient; and groups can be self-policing in matters of compliance with management contracts.

Cooperative arrangements already exist. Farmer groups and associations are commonly linked through a business objective, usually related to production for a market. They have procedures to enforce quality control, collect and administer payments, promote group cooperation, and implement sanctions - because non-compliance affects the quality of the final produce and the competitiveness of the group. Farmers are willing to pay fees (up-front, or as a proportion of their produce) to deal with the collective costs. Group structures are usually solid; decision-making is at the group level, and so are monitoring and dealing with breaches of rules. These same groups could become water services providers or local Water Resources Management Groups, undertaking and policing compliance with the terms of Green Water Credits as part of their own quality-control package.

5.4.3 Extension services

Existing government institutions have significant technical capacity and experience in training and capacity-building. Agencies of the Ministry of Agriculture and Ministry of Water and Irrigation have long experience of working with farmers' groups; however, they do not always reach the most vulnerable farmers or key areas for water management.

6 Legal, Institutional and Financial framework

6.1 Legal and institutional framework

The feasibility and viability of Green Water Credits in Kenya depends upon the current institutional reforms, aimed at integrated water management and valuing water as an economic good, not solely as a social good. The introduction of Green Water Credits, as a market-based mechanism supporting these reforms, is timely.

Responsibility for water resources management is vested in the Water Resources Management Authority (WRMA). Management is devolved to the river basin level and it is intended to draw upon local knowledge and experience through the participation of water users and managers at the local level. It is not yet clear how authority will be devolved or how the various government and non-government agencies and civil-society groups will work together - so it is not appropriate for the proof of concept to construct a detailed institutional framework for Green Water Credits; there are several options.

A public–private partnership is required embracing, on the one side, the buyers - both government agencies representing the public interest and private-sector water users; on the other side, the sellers - the farmers or farmers' groups who will provide the service. Most schemes of payments for environmental services also have an intermediary agency to manage the operation of the scheme.

Service providers

In the Upper Tana, and typically throughout the developing world, the service providers are smallholders who manage no more than a hectare, often without legal title. This is a disparate group in terms of education, technical and managerial capacity. From the point of view of Green Water Credits, organisation of these many thousands of households into autonomous groups that can operate as larger management units has several advantages:

1. More effective control of runoff and soil erosion;
2. Groups can be served more effectively by extension services and provide mutual support;
3. Groups have a more effective voice in negotiations. Farmers representatives need to be involved in developing the terms of contracts - content, obligations, duration, rates of payment; there is a history of farmers entering into agreements without understanding the consequences;
4. Groups are able to monitor compliance with the terms of the contract and apply sanctions in the case of non-compliance;
5. Groups have established mechanisms for receiving and managing credits on behalf of their members.

Service users

This is also a disparate group. Large water-users like KenGen, Nairobi Water and large irrigators have well-defined needs, individual capacity to represent their interests, and financial resources to contribute to a Green Water Credits Fund or, alternatively, to enter into Green Water Credits arrangements in their own right. There are also growers who are both water abstractors, for supplementary irrigation, and water suppliers, through their rain-fed operations.

The wider public interest, including maintenance of environmental services may be represented by government agencies and NGOs. Wider international or global interests may be represented by international agencies, donors and investors.

Management

A few buyers are well able to manage their own contracts with service providers. However, there is a general case for an independent intermediary to:

1. Assess water resources, demand, and optimum allocation;
2. Assess opportunities to maximise the resource through land use and management;
3. Appraise costs and benefits of green water management;
4. Establish a platform for negotiation between land users, as service providers, and water users, as buyers of this service;
5. Establish a mechanism for collection and payment of credits;
6. Establish arrangements for claims, verification, and settlement of disputes.

The WRMA is already established as the legally responsible authority for water resources management. It is mandated to undertake the first two tasks through Catchment Management Strategic Plans. It could provide a platform for negotiations between the water users and the service providers and take on the further duties of Green Water Credits contract management.

In addition to the WRMA, agencies of the Ministry of Agriculture, like KARI and NALEP, are already well placed to develop viable green water management packages, match these packages with local biophysical and social circumstances, and provide practical training in their implementation.

However, none of these institutions is set up for fund management and multiple financial transactions; these skills reside in financial institutions.

6.2 Financial mechanism

6.2.1 Functions

There are three essential financial functions:

1. Collection of fees from water users and contributions from general taxation and outside investors, to be held in a Green Water Credits Fund;
2. Management of the Fund;
3. Payment of credits to service providers. Within the administration at national level, cash payments to farmers is a sensitive issue, recalling former policy of subsidising farmers for soil and water conservation - which is now in disfavour. At local level, both public farmers supporting agencies and farmers recognise the real need for material inputs, e.g. by cash or in-kind payments. However, monetary transactions underpin all sectors of the economy, including the farm sector; few other direct incentives are available – possibilities include credit, or vouchers for schooling, livestock or other items, and many of these are gender-sensitive. In any case, these transactions must have an appropriate contractual basis and monitoring of performance.

6.2.2 Options for financial structure

Various structures for payments for environmental services operate elsewhere (Grieg-Gran and others 2006):

- *Direct contracts between buyers and sellers*: e.g. the La Esperanza Hydro-power project in Costa Rica signed a 99-year contract with the Monteverde Conservation League to maintain the watershed protection provided by 3000 ha of cloud forest;
- *Intermediar*y-based transactions: where a contract is negotiated between an intermediary and the buyers, on one hand, and the sellers, on the other hand. The intermediary may be a government agency or an NGO; this category also includes trust funds which pool contributions made by various water users, , e.g. the Water Conservation Fund in Ecuador;
- Area-based schemes: where rules and rates of payment are set out in national or local regulations, usually after negotiation. An intermediary organization may be involved in administering the contracts. Examples include payments for environmental services in Mexico and Costa Rica;
- Product-based mechanisms: whereby producers who meet the requirements of certification schemes (e.g. salmon-safe certificates in the USA) receive premium prices and improved market access;
- Sophisticated trading mechanisms: such as credits, licences and use rights. These have been used mainly in developed countries, e.g. salinity credits and open auctions to provide environmental services in Australia.

In developing countries, simple mechanisms like contracts have mostly been used and intermediaries have played an important role in bringing buyers and sellers together. It is vital that the intermediary be well-established and adequately resourced.

Government may choose to contribute to a managed fund out of general taxation or from earmarked funds, such as GEF facilities.

6.2.3 Payment mechanisms

Existing micro-finance agencies and their parent financial services organisations have the capacity and both public and international trust to manage small payments and large funds. It is essential to avoid transaction costs swallowing a large proportion of the finance available. A cost-effective mechanism for numerous small payments, such as will be necessary for Green Water Credits, has been tested by K-Rep Bank; it uses the existing and widely accessible GSM infrastructure and technologies, which include:

- *SokoTele* disbursement terminals at the potential water buyers or at a central GWC Fund;
- A ‘smart card’ enables the service provider to withdraw money at local outlets that have a mobile phone connection.

The system incorporates procedures for registration, agreement on disbursement between water buyer and services provided by the farmer, and can generate a legally valid record of all transactions, both electronically and on paper.

6.2.4 Establishment of a management structure for Kenya

Green Water Credits makes a market in water management services. The first step is to bring together the interested parties in a high-level Steering Group to establish the ground rules and steer the evolution of the process. This Steering Group should represent, on the one hand, *the buyers* - the government, representing the public interest, para-statal agencies mandated to provide public services, and private-sector water users; and, on the other hand, representatives of *the sellers* – the land users.

The Steering Group may chart directions and set ground rules and targets but it cannot manage the technical details and information flows of integrated water management, negotiations between buyers and sellers, the establishment of a financial mechanism, or contracts between buyers and sellers. For a national scheme, an Executing Agency, independent of both buyers and sellers would be the best option. In Kenya, the Water Resources Management Agency is already established with a mandate for integrated water management and is already developing a fee-based funding mechanism. It can take on board many aspects of the Green Water Credits process and appears to be an obvious choice as Executing Agency. It does not have all the necessary technical and financial capacity but these aspects can be handled by partners in the public and the private sector.

7 Conclusion

The proof of concept demonstrates the link between land use and management in the catchment and downstream water supply, river regulation and siltation. Practical ways to assess water resources, optimise water allocation, and calculate costs and benefits are also demonstrated - or developed for the purpose in the case of the water allocation and planning tool WEAP. The worth of water in all its competing uses is estimated and procedures established for more rigorous appraisal. Finally, the legal and institutional framework and a range of possible financial mechanisms for Green Water Credits are examined.

All water users in the Tana basin face large, rapidly-growing, un-met demands; land degradation, regulation of river flow and flood mitigation are also critical issues; business-as-usual is not an option. The situation may be much improved by integrated water management: linking the management of land and water, *green* and *blue* water; upstream and downstream interests, and the public and private sectors. Simple and effective green water management practices are well known but there is an implementation deficit. This study demonstrates that, in the case of poor farmers who receive low prices for their products, green water management is not financially viable unless additional incentives are provided. *This gap is the reason for Green Water Credits*.

Operation will depend on cooperation between farmers. Good examples of cooperation are already in place; these might be built upon to create local-level water resources management groups, able to enter into contracts with a commissioning organisation and operating a degree of self-policing. Incentives may be provided by cash payments, revolving credit arrangements and/or in-kind rewards.

First estimates suggest that increased water revenues, alone, will cover the marginal cost of conservation measures. In the case of siltation of reservoirs, focusing efforts on the relatively small areas of the catchment that are responsible for most of the sediment load can yield immediate and large financial benefits. The proof of concept has, perforce, used easily-accessible data and crude indicators. Therefore, all our assumptions are conservative. Better data will narrow the bounds of uncertainty but are unlikely to change the conclusions.

In Kenya, reform of the water sector is a window of opportunity to address not just the water crisis but, also, the underlying issues of land degradation and rural poverty. The technical tools are to hand and comparable payments for environmental services are operating in several parts of the world. Some of the institutions needed to manage Green Water Credits are in place, in particular the WRMA which is developing Catchment Management Strategies which may double as business plans; Green Water Credits offer a mechanism by which many of its goals may be achieved.

The Green Water Credits concept is proven: the spark has jumped the gap. If in Kenya, why not elsewhere?

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Green Water Credits reports

GWC 1	*Basin identification*	Droogers P and others 2006
GWC 2	*Lessons learned from payments for environmental services*	Grieg-Gran M and others 2006
GWC 3	*Green and blue water resources and assessment of improved soil and water management scenarios using an integrated modelling framework.*	Kauffman JH and others 2007
GWC 4	*Quantifying water usage and demand in the Tana River basin: an analysis using the Water and Evaluation and Planning Tool (WEAP)*	Hoff H and others 2007
GWC 5	*Farmers' adoption of soil and water conservation: the potential role of payments for watershed services*	Porras I and others 2007
GWC 6	*Political, institutional and financial framework for Green Water Credits in Kenya*	Meijerink G and others 2007
GWC 7	*The spark has jumped the gap. Green Water Credits proof of concept*	Dent DL and JH Kauffman 2007