Essentials for Implementation of Improved Green Water Management in Muooni Catchment, Machakos District of Kenya

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Abstract

Global climatic, demographic and economic changes affect “blue water” accessible in streams, lakes and groundwater under the effects of deforestation. Yet, two thirds of water resources referred to as “green water” are retained by plants for their own use. Their depletion has an impact on agricultural lands productivity. There is thus need for managing skilfully green water. A study conducted in Muooni Catchment of Kenya assessed the need for Green Water Saving (GWS) in that area and its value-addition to the supply of crop water requirement. This paper illustrates the use of operational research to simulate the “Economic Order Quantity” (EOQ) and to cost green water supply in Muooni Catchment of Machakos District, in Eastern Province of Kenya. Results show that farmers’ water demand is more than their crop water requirement. They tend to use inefficient cropping methods and water management techniques that significantly increase their farming water losses. Considerable investments in GWS are thus needed to increase by at least 50% the one-tenth accessible blue water, and foster a green revolution in ASATs in general, and Muooni Catchment in particular. This may prevent water disasters and crop failures, as well as alleviate farmers’ poverty in these areas.

Keywords: Green water saving, Crop water requirement; Economic order quantity (EOQ), Farmer’s water demand, Integrated watershed management (IWM), Rainfall fluctuation.

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Introduction

Water crises are arising worldwide due to changes in patterns of climate, population and economic growth, and other natural and social patterns (Uitto and Schneider, 1997; Shakya, 2001). Human appropriation of surface and ground water, changes in land-use and land cover, release of pollutants into the environment and other pressures contribute to this increased water stress. These have serious consequences on the living of people and ecological systems that depend on the availability of quality water resources and its temporal distribution (Huggins, 2002; Gleditsch et al., 2004). The subsequent degradation of water resources and the lack of access to safe water threaten human welfare and development, and any effort to alleviate poverty in many parts of the world (USAID, 2009a). Consequently, human beings suffer from water stress, of which they actually are main causal agents. So, “the great challenge we face is to get to business not as usual” by involving all stakeholders in the search of innovative ways for sustainable management of water resources (Berntell, 2008). The implementation of GWS schemes is likely to be such an innovative approach of enhancing co-operation between upstream and downstream stakeholders toward sustainable management of their watershed resources.

What green water entails

Green water is defined as “the water held in the soil. It is the largest fresh water resource, but it can only be used in situ, by plants” (Falkenmark and Rockström, 2004). Managing green water together gives an opportunity to stakeholders to work...
toward safeguarding their “blue water” and assuring food security to all. “Blue water is defined as fresh water that can be tapped, from rivers and streams, or groundwater” (Wilschut, 2010). GWS schemes involve mechanisms dealing with allocation of Evapo-Transpiration Quotas (ETQ) to farmers, Payments for Watershed Services (PWS) and any other kind of compensation by “rich” stakeholders to “poor” farmers who deliver environmental services. Environmental services generally delivered in a watershed include planting of trees and conservation of water source, control of soil erosion, desiltation of drainage channels and water storages, control of pollution, etc. (Porras et al., 2007; Bastiaanssen and Bingfang, 2008). Though unrecognised and unrewarded, Geertema, (Wilschut and Kauffman, 2010) argue that green water management techniques are practically effective, biophysically possible, economically feasible and socially acceptable when it comes to satisfy the needs of both upstream farmers and downstream water users, especially in Sub-Saharan Africa. They are good incentives for a wider uptake of soil and water conservation measures.

Sub-Saharan Africa has high potential green water resources, though about 70% of its land is either desert, arid, semi-arid or dry sub-humid areas with poor rainfall and less productive agricultural lands (WRI, 2003).

Figure 1. Africa’s Rainfall Map (UNEP, 2002)

Drought in Africa is likely due to lack of alternative sources of water such as rainwater harvesting and storage (World Bank, 2007). Changes in the local microclimate as well as in the regional and global climates only affect the long term availability of water and food as well as human health and economic development in most Sub-Saharan African countries, and especially in drought prone areas (USAID, 2009; Immerzeel et al., 2010). Major cities of Eastern and Southern Africa are increasingly feeling their effects. If the present trends continue, approximately 2.8 billion people will suffer of absolute water shortage by 2025, and two thirds of the global population will be suffering of water stress (UNEP, 2002; ISRIC, 2008).

Kenya is among the highly vulnerable countries to climate change risks. About 85% of its land is either arid or semi-arid, while more than 55% of its population is extremely poor (DeWit and Stankiewicz, 2006; GoK, 2007). Most of these people live in rural areas where agriculture is the major livelihood. The Ministry of Water and Irrigation (MWI) has engaged in the rehabilitation of major catchment areas with the aim of augmenting water flows in all the drainage systems (Ngurari, 2009). An integrated watershed management (IWM) that focuses on stakeholders’ participation supports this policy (Förch et al., 2006; WRMA, 2010).

Green water saving in the context of IWM

Integrated Watershed Management (IWM) emerged as a sustainable way of preventing potential conflicts between economic growth and social welfare as well as the conservation of natural ecosystems (UNEP, 1989). IWM was designed as a coordinated management of various resources in the watershed (water, soil, biomas, energy, animal, human, etc.) to provide sustainable interactions between social, economic and environmental development (Foerch et al., 2005). The Global Water Partnership (GWP) defines it as an “Integrated Water Resource Management (IWRM)” that “promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems” (GWP, 2000). This suggests that the management of water resource is to be supplemented by that of other natural resources depend on the watershed environment to increase the efficiency of agriculture and other economic activities. Such an approach would not only preserve the vitality of natural ecosystems but also satisfy the needs of human beings toward the achievement of social equity and economic development. Thus, integrated watershed management (IWM) becomes “an integrated approach of natural resource management, focusing on sustainable protection of food security and poverty reduction” (Förch et al., 2005). IWM provides a useful framework for action. It acknowledges the complex human-environment interactions and feedbacks in the watershed (UNDP, 2007). In a nutshell, IWM was primarily designed to address issues occurring at a river basin scale by linking food
security and poverty reduction with the management of water, land and other watershed resources (Figure 2). It was not expected to be a panacea for all social, economic and environmental problems.

The implementation of the concept of IWM in ASATs has achieved remarkable results (Ericksen, 1998; Förch et al., 2006, 2007, and 2008; Thiemann et al., 2009). Generally, the strategy most often involved an upstream-downstream cooperation for the management of about one tenth accessible soil moisture generated by direct transfer of rainfall into the soil (Kauffman et al., 2007). These surface runoff, interflow and groundwater resources are known as “blue water” and make only one third of the total soil moisture. The remaining two thirds are held in the soil by plants for their own use and referred to as “green water” (Dent, 2006; Dent and Kauffman, 2006)( see Figure 2).

Figure 2. Green and Blue Waters in a Watershed (ISRIC, 2008)

If efforts are made to invest in green water harvesting, the one tenth accessible blue water in streams, lakes, and groundwater may be increased by at least 50% as witnessed by the green revolution in South-East Asia in the 1960s (GRAIN Briefing, 2007; Bastiaanssen and Bingfang, 2008). Green Water Saving (GWS) schemes are therefore mechanisms of safeguarding water resources in the catchment through simultaneous actions of water and land conservation at source, cropping and tree planting by local stakeholders (Luwesi, 2010). GWS are more than simple land-use practices or soil conservation measures. They are part of a long-term water resources management strategy that addresses both water scarcity and rural poverty through planning and management of all available water resources from supply to demand, and fair payments for environmental services in the watershed by local stakeholders (Grieg-Gran et al., 2006; Meijerink et al., 2007). The fact that they intend to fight local stakeholders’ poverty while conserving the watershed environment makes them innovative “Clean Development Mechanisms” (CDMs) (Porras et al., 2007). Though, unrecognised and unrewarded, GWS schemes remain real water saving programmes that are being used to sustain the management of irrigation schemes, decision-making on resource allocation and disaster mitigation in water-scarce areas. They are also pro-poor schemes initiated by local stakeholders at the lowest level of environmental management, in lieu of poverty alleviation mechanisms initiated by governmental institutions and/or their partners (ISRIC, 2008).

Needs assessment for implementation of GWS Schemes

The availability of green water in a certain environment determines the resilience of its ecosystems and their productivity in agriculture. Water Vision (2000) quoted by (Mati, 2006) declared that Water crises were not “about too little water but about managing water badly such that billions of people and the environment suffer badly”. Due to land degradation, malfunctioning ecosystems result in unpredictable overflows and shortage of water in the watershed (Hoff et al., 2007). Rills in highlands with sheet flow in small channels quickly result in inter-rills mid-stream and gullies downstream lead to sediment loads in drainage systems and dams. Thus, prior to implementation of any GWS scheme, the management of the watershed shall be able to assess the full cost of social, economic and environmental factors affecting water availability. By implementing efficient land-use practices, green water resource as well as their blue water counterpart will be preserved and stakeholders’ poverty alleviated (Wilschut, 2010).

GWS Schemes are therefore investments in land and people with a focus on water, vegetation and soil conservation by upstream stakeholders in order to allow water flow freely and massively downstream. To increase the economic sustainability of both upstream, midstream and downstream riparian stakeholders, the designers of such schemes need to provide incentives to those upstream and midstream to better protect the land so as to release enough water downstream for both mankind and ecosystems. (Ngurari, 2009) highlights that fact when recalling the 2009 drought in Kenya. During that period, the siltation of river channels and reservoirs was lowering water table, resulting in failure of wells, springs, irrigation schemes and hydropower plants. However early 2010, riverflows became uncontrollable in some parts of the country resulting in a cycle of
high peak flows, while others experienced the 2009 fate with highly reduced flows or no dry-season flow. As consequences, there was less water to sustain natural ecosystems and hydropower production, less water for irrigation and unreliable urban water supply for domestic use, especially in the dry season (KRC, 2009). Moreover, excess water flow accompanied by silting caused more damages to turbines and dam reservoirs, as well as crop failures and tree fall in flooded areas (KRC, 2010).

One major goal of implementation of GWS is to foster integrated watershed management in Kenya through rainwater harvesting, and increase of soil moisture during drought or its decrease during flood. This policy may encompass activities pertaining to soil erosion control and water conservation, the rehabilitation of rangelands (including water for livestock and fodder) and wetlands. Other GWS schemes may involve agricultural activities that increase soil fertility by the use of manures, fertilisers, and residues. Others may deal with conservation agriculture (through deep tillage and mulching), and agronomic practices that optimise water uptake, climatic variability mitigation, saline water and waste water treatment, and capacity building programmes in IWM. Therefore, the overall supply of a GWS scheme shall include various interventions among which the supplementation of irrigation water and drainage runoff (surface and subsurface, seasonal and perennial), and soil conservation measures. These mechanisms may assist in achieving sustainability in the watershed and avoiding recurrent water shortages upstream and midstream, while there is overflow downstream.

A strategic assessment is needed to determine the main water issues on stake, the competing claims, the existing land and water rights. The needs assessment will also indicate the persons who are legally mandated to modify the above rights, the beneficiaries and those designated to compensate them. Following such a needs assessment, the implementation of the GWS Scheme will be based on a holistic approach of water resources management. The latter will imply “any kind of human action that influences the natural flow of water to farmers’ crops, or any form of agriculture that takes advantage of naturally rising or falling water levels for crop production” (FAO, 1995). Those upstream and midstream will be provided incentives to conserve the watershed and release water resource downstream. Other trade-offs between competing claims among upstream, midstream and downstream stakeholders will also be made in the context of the GWS scheme. Thus, action can be taken to optimize water flows and mitigate water related hazards.

MATERIALS AND METHODS

Scientific needs assessment is needed to value any claim of right of demand and supply of GWS service. This may include direct observations, Focus Group Discussions (FGDs), analysis of Strengths, Weaknesses, Opportunities and Threats (SWOT analysis), Remote Sensing, GIS and Soil Water Analysis Tools (SWAT), as well as statistics and operational research. Physical research and environmental modelling have proved to be of much assistance with regards to computing green water demand. For instance, remote sensing, GIS and Soil Water Analysis Tools (SWAT) assist in developing different scenarios of green water demand through determination of potential and actual evapo-transpiration (ET per mm of annual rainfall), biomass production (Kg of yield per m2 of land area), and water productivity (Kg of yield per m3 of water). Using these data, Inventory models may assist to compute the Economic Order Quantity (EOQ) and the costs of plant water supply. Otherwise, this tool would assist upstream stakeholders to determine the quantity and the price of green water to be supplied midstream and downstream under normal, above normal and below normal scenarios of water availability.

The use of inventory models to compute the economic value of green water is not yet fully explored in the water sector. Yet, it can facilitate efficient delivery and use of green water in the catchments under fluctuating rainfall regimes. It may assist development planners to enhance irrigation efficiency and crop water productivity in areas where real water savings can be applied to limit high water consumption. This study illustrates the use of operational research in the design and implementation of a GWS scheme in Muoni Catchment of Machakos District (Eastern Province, Kenya).

Operational valuation of GWS

As indicated above, GWS Schemes are expected to affect positively water availability in streams lakes and underground. This fact is not yet fully recognized due to the lack of assessment of the full value-added of green water to the available blue water in the environment. Green water is simply said to be the equivalent of crop water requirement. The latter is computed as the total evapo-transpiration from vegetated areas. Yet, water use by plants is likely to vary under different conditions of rainfall and soil moisture. To determine green water value-added one may consider its impact on ecosystems resilience, agricultural productivity, and disaster mitigation. This will lead to the recognition of the full cost of water as an environmental, an economic and a social commodity.

Green water supply may be computed as farming water demand and valued under normal (NOR), above normal (ANOR) and below normal (BNOR) rainfall regimes. The total farming water cost function will comprise a cost of transaction, an opportunity cost, and an external cost (cost of saving or shortage cost) under the above scenarios of water availability. Total Farming water demand (Wf) computed under any rainfall regime will be as follows (Formula 1):
**RESULTS AND DISCUSSION**

*Results*

(Luwesi, 2009) conducted a survey on 66 farms operating at Muooni dam site. The study revealed that water stress and land degradation were major causes of food insecurity and poverty outreach in marginal and dry lands of the catchment. Both anthropogenic and environmental factors affected efficient use of water and land by farmers. There resulted in increased cost of farming water leading to high risk of crop failure, especially under drought. However, Mann-Witney U-test and Spearman’s rank correlation indicated at 99.8% confidence degree that farming activities assessed at Muooni dam site did not have a significant impact on its soil erosion and water over-abstraction. Farmers’ poor education and income did likely not allow them detect early effects of soil erosion and multiple cropping overuse, while El Niño floods and droughts amplified these impacts by loading more than usual sediments in Muooni dam reservoir. These externalities affected water availability in Muooni dam at a decreasing rate of 6.2% each year. Spearman’s Rho test attributed 65.7% of the total variation of the dam’s active water storage to the obsolescence of its reservoir logistics with 99.5% confidence degree. The remaining 34.3% were explained by the reservoir sedimentation and water over-abstraction by eucalyptus and other alien trees planted in the catchment. The decreasing water levels in Muooni dam threatened smallholder farms’ yield and income through increased farming water shortage costs and the cost of excess loss of fertile soil. This constrained farmers to use less water than required by their plants, especially during drought.

Operational research simulations revealed that Large Scale Farmers (LSF), Medium Scale Farmers (MSF) and Small Scale Farmers (SSF) were just ordering 28.9%, 12.2% and 4.4% of their respective actual crop water requirements. An average increase of 175%, 518% and 1,427% of their actual total costs was observed under ANOR, NOR and BNOR scenarios, respectively. This implies that 1 m$^3$ of farming water, which was normally to cost KSH 250 (equivalent of USD 3.6, for USD...
Beside the changing climate and environmental patterns, water crises in Muooni Catchment are mainly explained by a bad management of green water resources (Luwesi et al., 2010; Ngonzo et al., 2010). A good management of green water requires the use of innovative farming methods and hydro-policies to minimize significantly farming water losses. Efficient farming methods may include crop selection, use of High Yield Varieties (HYVs) and specialization to two or three water friendly crop species. They had also to optimize their water demand to the EOQ level, or to the LAC level, or at least to the MES level, if efficiency was to be achieved. This would have increased the average of their actual water demand by at least 36%, 129% and 972% under the ANOR, NOR and BNOR rainfall regimes, respectively.

DISCUSSION

Successful GWS schemes have been founded on a clear assessment of economic incentives of all stakeholders, which were lead them join the scheme and comply with its rules. Some of these incentives are the empowerment of stakeholders to participate in the planning and implementation processes, and a fair share of the benefits that are expected from it. For effectiveness, the Government of Kenya will need to design an appropriate institutional framework. This is expected to incorporate GWS schemes into a sustainable development plan and allow the mobilisation of resources from direct stakeholders for equitable distribution of watershed resources.
well as water reserves in the streams, lakes and underground. They would also need to maintain existing water infrastructures and wetlands to reduce the siltation of drainage systems and reservoirs so that water quality and quantity can improve midstream and downstream. For that reason, farmers downstream need to use part of their increased earnings to pay upstream stakeholders for watershed management.

Finally, prior to implementation of any GWS scheme, local stakeholders will have to establish agreed ways to assess the available water resource and its demands, as well as ways to value GWS services and the cost of their management. They shall also assess ways to optimise the resource availability through efficient land use management before establishing any platform for negotiation between interested parties. They will also need to ensure that each party is well informed to get fully involved in the process. They shall seek optimum allocation of water, and agree on a “fair price” for specified management activities that achieve optimum green water supply. This will allow them establish a mechanism for collection and allocation of credits, as well as arrangements for claims, verification, and settlement of disputes.

Kenya as most African countries faces the great challenge of shifting from blue water management as usual to a “green water management revolution”. As shown in the case of Muoni Catchment, there is already need for skilful management of green water to attain the targets of the Millenium Development Goals (MDGs). An estimate of 85% of crops water requirement may be saved from better management of water in rainfed agriculture. However, experience has shown that policymakers are stuck in their routine, undervaluing any new knowledge emanating from any enlightened source. This makes difficult the implementation of IWM at the lowest level of environmental management, since no changes in water policies and investments are to be expected. Therefore, innovative GWS schemes are likely to boost policy shift from “business as usual” to upstream-downstream stakeholders’ cooperation in terms of rainwater harvesting, allocation of Evapo-Transpiration quotas (ETQ), Green Water Credits (GWC), Payments for Watershed Services (PWS) and other Clean Development Mechanisms (CDMs). That would make possible the control of water overuse in agriculture, the conservation of catchment areas and the mitigation of hazards.

All stakeholders will need to ensure a long lasting cooperation with the public sector through implementation of the water sector reforms. This cooperation may lead to the institutionalisation of public involvement in public affairs. This in turn may give rise to innovative methods of management of natural resources leading to the recognition and promotion of GWS schemes. That is how a genuine “green water management revolution” can be achieved in Kenya.

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