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Green Water Credits for Sustainable Agriculture and Forestry in Arid and Semi-Arid Tropics of Kenya

Rose A. Akombo^{1,2*}, Cush N. Luwesi², Chris A. Shisanya² and Joy A. Obando²

1-Climate Change Programme, Kenya Forest Service (KFS)

2-Department of Geography, Kenyatta University (KU) Nairobi, Kenya

Corresponding Author: Rose A. Akombo

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ABSTRACT

Farmers living in most Arid and Semi-Arid Tropics (ASATs) of Kenya face the great challenge of fetching water from alternative sources to curb the effect of drought on rainfed agriculture and forestry. They recourse to traditional Soil and Water Conservation (SWC) measures and other available technologies for saving blue water. Yet, these technologies have become ineffective, owing to the intensity of water disasters arising from climate change and the unsound management of the catchment's land and water resources. Hence, Green Water Credits (GWC) schemes have been propounded to be bio-physically needed, technologically possible, politically and socially acceptable, and economically feasible for ensuring adaptation to and mitigation of climate related water disasters. These schemes significantly rely on effective SWC measures, hydro-policies, agro-technologies and Payments for Environmental Services (PES) to mitigate the effects of drought on farming and forestry. This paper reveals the strengths and challenges facing these schemes in the ASATs of Kenya. Policy makers need to address these issues prior to implementing GWC schemes

Keywords: *Green Water, Forestry, Semi-Arid Tropics, Kenya*

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INTRODUCTION

The agricultural production in most Arid and Semi-Arid Tropics (ASATs) is being significantly affected by the changing weather patterns (UNEP, 2008; Immerzeel, 2010). Not only rain-fed agriculture is mainly threatened by climate change but also by human induced activities and other anthropogenic factors (USAID, 2009). Most climate scientists predict that water related hazards will escalate in regions where forests and wetlands have been depleted, since the latter are known to absorb excess water losses during floods and soften the effects of droughts (Ogallo, 1999; Bates, 2008). Hence, the high vulnerability of agriculture in ASATs is said to be mainly linked to deforestation, which leads to the depletion of "green water" type of freshwater (Rockström, 2003). Green water is a vital part of ecosystems just like rainfall and soil water. Its availability and quality determines ecosystem productivity, both in agriculture and natural ecosystems. However, its depletion results in the disturbance of the functioning of biological systems and other ecological systems (Ekbom and Sterner, 2007; Ngonzo, 2010).

In effect, green water represents two thirds (2/3) of the total amount of freshwater resources, and generates the most important part of soil moisture held by plants for their own use (Falkenmark and Rockström, 2004; Malesu, 2007). Therefore, plants have to share one-tenth (1/3) of all fresh water resources, referred to as "blue water", with all the remaining biological and ecological systems. Yet, this renewable freshwater is limited per capita across the globe, and shall first be tapped from rivers, streams and groundwater, and is (Kauffman, 2007; ISRIC, 2008). Consequently, water resource management shall better focus on developing "green water" rather than "blue water" (for saving surface and ground water). That is the greatest challenge that humanity has to face: "to get to business not as usual" by involving all stakeholders in the search of innovative ways for sustainable management of green water resources (Berntell, 2008). Such types of innovations are known as Green

Water Saving (GWS). The latter includes hydro-policies, agro-technologies and Payments for Environmental Services (PES) schemes such as Green Water Credits (GWCs), Evapo-Transpiration Quotas (ETQ) allocations to farmers, Payments for Watershed Services (PWS), to name but a few (Luwesi and Badr, 2012). This paper focuses on Green Water Credits (GWCs) and Payments for Watershed Services (PWS) schemes. Prior to describing these innovative schemes, it is worth looking at different water saving mechanisms used by Kenyan farmers in ASATs.

Farming Water Saving Strategies in ASATs of Kenya

Managing water together gives an opportunity to farmers to work toward safeguarding their “blue water” and assuring their livelihood and food security to all. Living in a drought stricken area, farmers feel abandoned by the Government of Kenya, whose policy has failed to implement a strong Public-Private Partnership (PPP) in their rural areas (Luwesi, 2012). Policy routine has led to high concentration of investments in agricultural water in areas where rainfall is high, including western and central regions as well as parts of Rift Valley, coast and eastern region without providing alternatives to surface water (Zhang, 2010; Fig. 1). Most farmers living in ASATs have thus resolved to rely on traditional water conservation practices. “While this knowledge is not formalized or uniformly distributed, it is a key resource which should be recognized and incorporated in a more participatory wetland management and planning process” (Dixon, 2005). Subramanian (2001) indicates that “Water problems in developed countries have been solved only by reservoir storage at different stages of the river flow”. So, if water shortage problems are solved more quickly in the ASALS of India rather than humid regions, it is simply because of adaptation of traditional water storage systems to drought, mainly using deep ponds, storage wells and underground tanks.

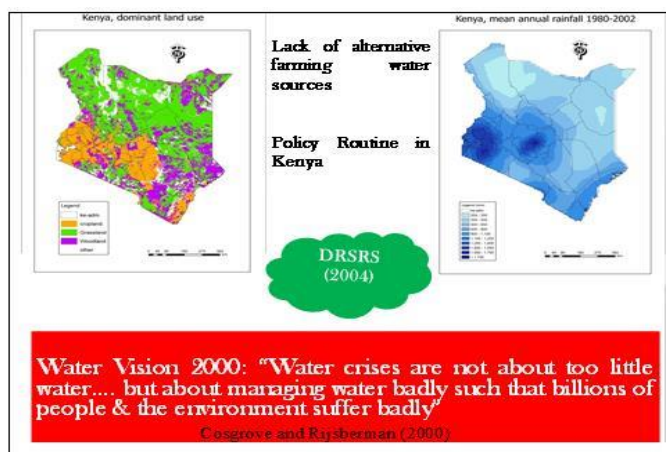


Figure 1. Policy routine correlated with rainfed agriculture (adapted after Luwesi et al., 2012)

Likewise, Cheserek (2005) lauded some populations of the Rift Valley of Kenya for upholding traditional SWC measures to cope with drought. For instance, the Marakwet agro-pastoralists use traditional SWC strategies to protect their water courses against droughts and mitigate subsequent conflicts over the little resource available through equitable allocation plans. Tiffen and Mortimore (2002) demonstrated how local communities in Machakos District of Kenya ensured environmental stability and survival of agricultural land uses during drought through effective SWC measures. This skilful use of indigenous knowledge enabled them to cope with increasing population pressure on land resources. Thus, a careful application of SWC techniques is a key to successful adaptation to environmental changes. However, this is likely not to be the case in the course of climate change.

Most traditional practices fail the test of mitigating the effects of water shortage (Shakya, 2001; Van Aalst, 2006; Sehring, 2008). For instance, Shisanya (2005) observed that farmers living in the rural areas of Kakamega in western Kenya, and more precisely 58% of them, are facing serious challenges related to potable water accessibility during drought. The recourse to boreholes, which result in such hardships as the lack of technical know-how, the inadequacy of their means of transport and finances for assuring permanent water supply, among others. These factors impact directly on the maintenance of the catchment environment through increased socio-economic externalities leading to deforestation, soil erosion, water pollution and others.

It arises from this analytical description that farming water saving strategies, whether within a modern or traditional context encompass two main sets of mechanisms: “Blue Water Supply” (BWS) projects on one end, and “Green Water Saving” (GWS) schemes on the other. The construction of dams, aerial and ground tanks within major catchment areas, and the drilling of boreholes to tap groundwater, which are *primum non nocere*, are typical BWS projects (Ledec and Quintero,

2003; World Bank, 2008). However, investments in people, their land and ecological systems are imbedded in GWS schemes and determine the availability and the quality of water resource and its temporal distribution (Huggins, 2002; Gleditsch, 2004). These schemes are mainly implemented through institutionalization of hydro-policies, agro-technologies, Soil and Water Conservation (SWC) measures and pro-poor schemes implemented within the PES framework (Ragab and Hamdy, 2004; Malesu, 2007; Reij, 2009).

GWS schemes involve a close co-operation between upstream and downstream farmers, those upstream being green water services' "sellers" and their downstream counterparts being "buyers" (Wunder, 2007). Henceforth, GWS schemes are "pro-poor" schemes initiated at the lowest level of environmental management by local stakeholders. They deal with "Payment for Environmental Services" (PES) by "rich" farmers to "poor" ones in order to foster a green revolution in ASALs through usage of SWC measures and hydro-political strategies (Ortega-Pacheco, 2009). A proper management of "green water" enhances rainwater infiltration into the soil and groundwater reserves thus resulting in increased water tables and thus surface runoff. They address the ever widening gap between water demand and supply, and ensure agriculture resilience to climate change in most ASALs. This has been demonstrated by several studies on the implementation of "Green Water Credits" (GWCs) schemes. Prior to discussing GWCs value added on agriculture resilience, the following section will focus on the distribution of both blue and green waters in the world.

Global Distribution of Green and Blue Waters

Scientists have demonstrated that the total rainfall received on the earth's surface is mainly kept in oceans and lakes as salty water (97.5%). Only 2.5% of the total precipitation is part of what is called "fresh water". Yet, only 0.4% of the world reserve of fresh water is available for production and consumption, the remainder being locked in glaciers and ice lands (2.1%) (Bates, 2008). About 65% the total accessible fresh water reserves are conserved by plants both in agriculture and the environment (Dent and Kauffman, 2007). Grasslands account for 31%, forest and woodlands 17%, crops 4%, other land cover 6% and arid lands keeping 5%. The remaining 38% are referred to as accessible base flow (11%) and storm runoff (27%), which is being partly allocated to irrigation (1.5%) with half of it being constituted as return flows (0.7%) (Fig. 2).

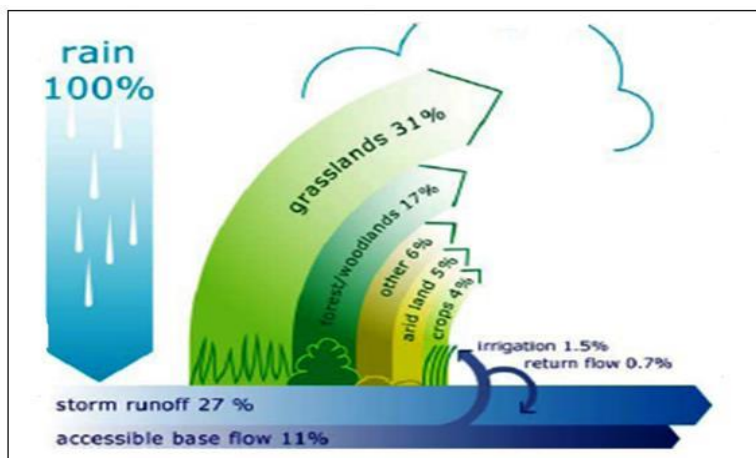


Figure 2. The distribution of green water and blue water across the globe (ISRIC, 2008)

Ericksen (1998) simulated the agricultural water use in the world to 69% of the accessible fresh water reserves, while the industrial share amounted to 23% and households' use for domestic purposes to 8% only. The African share for agricultural use of fresh water was estimated to 88%, industries accounted for 5% and households for 7% only. Consequently, Falkenmark and Rockström (2004) conclude that "green water is the water held in the soil. It is the largest fresh water resource, but it can only be used in situ, by plants". It represents about two thirds (2/3) of fresh water reserves but cannot be diverted to a different use, if it is not for usage by plants or soil moisture alone (Fig. 3). The remaining one third (1/3) is referred to as "blue water". "Blue water is defined as fresh water that can be tapped, from rivers and streams, or groundwater" though harvest and storage, diversion and pumping (Wilschut, 2010). How do Green Water Credits (GWCs) enhance soil moisture and water for sustainable farming? The following section discusses the value added of GWCs on agriculture resilience in ASATs.

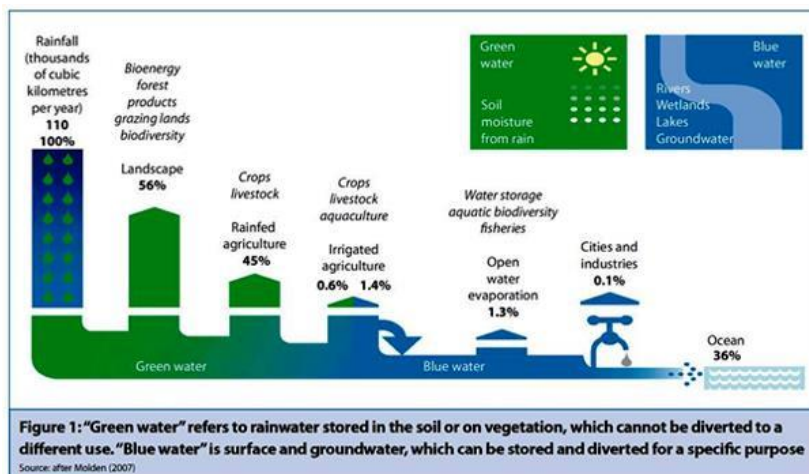


Figure 3. Green water occurrence versus blue water (UNEP, 2011)

Value Addition of Green Water Credits in Farming Water and Soil Moisture

To increase agriculture resilience to climate change scientists have suggested communities to put on strenuous efforts for accrue investments in Green Water Credits (GWC) in ASATs under the stewardship farmers' groups or a Water Users' Association (WUA) (Hoff, 2010). The foregoing literature review reveals the performance and "use value" of GWCs in agriculture in the course of climate change, particularly in Kenyan ASALs. Direct and indirect benefits include addressing issues of "adaptation and land use practices, soil and vegetation conditions, nutrient loss, water availability, physiological conditions, environmental degradation such as environmental pollution and desertification, pests and diseases, transportation, marketing and many other agricultural indicators, which are crucial to sustainable national development" (Arnon, 1992; Ogallo, 1999; Hulme, 2005). A clear understanding of these processes leads to monitoring changes in the quantity and the quality of water in order to predict, mitigate and adapt to water related disasters. More important, managing green water gives an opportunity to local stakeholders to work together toward safeguarding their "blue water" and assuring food security to all (Rockström, 2009; Scherr, 2011).

GWS Schemes are first and foremost investments in land and people with a focus on water, vegetation and soil conservation by upstream stakeholders in order to allow free and massive flow of water downstream (Wilschut, 2010). The assessment of GWCs' value added primarily involves unveiling the causes of hindrance of massive flow of water downstream to determine the type, the suitability and effectiveness of GWS services needed by local stakeholders (Geertsma, 2010). For instance Hessel, (2003) used Limburg Soil Erosion Model (LISEM) to simulate the effects of land use and management strategies for reducing runoff and erosion rates in the Danangou catchment in the Loess Plateau. The study found decreases in runoff and soil erosion of about 5 to 15% after implementation of SWC measures following the existing land use pattern. Nonetheless, there was decrease of 40 to 50% discharge and 50 to 60% soil loss under changing land use pattern in accordance with the steepness of the slope. Similarly, Liu, (2003) simulated the impact of climate and Land Use and Land Cover (LULC) changes on runoff in the Yellow River for the period 1980–1990 using Soil and Water Assessment Tool (SWAT). Their findings show that an increase of 1°C in temperature resulted in decreased runoff of 109% while land use change increased runoff by 10% in the source region of the Yellow River. Therefore, appropriate land management was required to maintain the catchment micro-climate and its runoff.

Similar results are report in Kenya by Hunink, (2010). The latter conducted a bio-physical assessment of Green Water Credit (GWC) in some selected sites of the Upper Tana Basin of Kenya by quantifying fluxes of green and blue water as well as sediment using SWAT. The study led to identifying potential target areas for awarding GWCs in the pilot operation based on their heterogeneities in terms of precipitation regime, topography, soil characteristics and land use. The SWAT model assisted in estimating the benefits of the management practices on erosion reduction and green and blue water flows in the basin. The analysis revealed that basin-wide implementation of tied ridges would lead to a reduction of sediment input into the Masinga reservoir of about a million tons, while mulching would reduce unproductive soil evaporation by more than 100 million cubic meters per year. The enhancement of groundwater recharge through the different practices would improve the usage of the natural storage capacity in the basin by about 20%. These benefits were quantified based on specific crops and sites.

Wilschut (2010) on the other hand used Remote Sensing (RS) to map land use activities going on in the Upper Tana Basin. This RS analysis was applied using two classification methods (rangelands and forest cover) based on the Support Vector Machine method, which proved to be more accurate than the Africover 2000 map that was in use. The study came up

with an updated and higher resolution land use map depicting hotspot areas and different land use types for each area, namely rangelands versus cereal farms; and forest cover versus tea, coffee and maize farms). This new land use map was said to be used to improve hydrological and erosion modelling. This would lead to a more accurate estimation of water resources and land degradation as well as improving the choice of GWC target areas.

Finally, Hoff, (2007) used the Water Evaluation And Planning (WEAP) model to develop and test options for matching water supply and water demand, and assessing upstream-downstream links for different options in terms of water sufficiency for un-met demand, costs and benefits in the Tana Basin of Kenya. The study shows all water uses therein have unmet demands, including hydro-power, municipal water utilities and irrigation. For instance, the Masinga Dam had lost over 30% of its capacity from 1982 to 2002. The study concluded that immediate decrease of unmet demands and rationally significant gains in hydro-power generation and urban water supply can be achieved by stopping the siltation of water reservoirs from small areas and farmlands. Hence, there was a need for implementing GWCs in some targeted areas. However, to be acceptable to local stakeholders, these GWCs schemes have to demonstrate high cost recovery, which dictates their economic feasibility and sustainability. The following section reports recent findings by Luwesi, (2012) in a study dealing with “the dilemma facing green water economy under changing micro-climatic conditions in Muooni Catchment (Machakos, Kenya).

Economic Challenges Facing Green Water Credits in Kenyan ASATs

Luwesi, (2012) conducted a survey in Muooni Catchment that involved 106 farmers from Muooni catchments, 15 in-depth interviews, one Focus Group Discussion (FGD) with 8 key informants, and hydro-geomorphologic field surveys. The latter dealt with river discharge and soil moisture measurements *in situ* using *Hydrometrie* current meter and *ThetaProbeML2x* Moisture meter, respectively. The river discharge was computed from estimates of velocity, length and depth of 6 cross-sections of the rivers under study, while the soil moisture was automatically measured by the machine from 30 soil points in selected farms. Besides the above on-farm survey, in-depth interviews, FGDs and field researches, data collection also encompassed large sets of secondary data on rainfall, temperature and discharge, as well as an extensive literature review. The analysis was based on a robust Performance Assessment and Evaluation (PAE) that encompassed a Bio-physical Needs Assessment (BNA), a Socio-Political Acceptability Appraisal (SPAA) and an Economic Viability Study (EVS).

Results show that climate change has significantly reduced water productivity in farming due to recurrent water shortages in Muooni Catchment. Farmers are facing increased mean temperatures of about 1.0⁰C per century ($R^2 = 0.863$) with subsequent decreases in mean rainfall of about 10 mm per century ($R^2 = 0.877$) and decreased river discharge of 1.2% downstream ($R^2 = 0.667$). To sustain their livelihoods, farmers have resorted to various SWC measures, which implementation has led to the “re-greening” of the catchment of about 19.4% (from 1,191.65 hectares in 1976 to 1,422.99 hectares in 2010). Even though the assessment of Land-Use/ Land Cover (LULC) change emphasized a clear depletion of natural vegetations, satellite images revealed an increase of “man-made forest” under the effects of agro-forestry. Despite this re-greening, farmers are still vulnerable to drought due to the intensity of hydro-climatic risks and inadequate LULC change, especially with regards to eucalyptus tree planting. Though environmentally needed and socially accepted, GWC schemes’ are still costly, economically inefficient and unprofitable for smallholder farms operating in Muooni Catchment, especially under drought conditions. This explains the low economic efficiency rates and Benefit-Cost Ratio (BCR) displayed by these schemes in Muooni (Table 1).

This table shows that GWC schemes’ BCR in Muooni was high under flooding scenario (BCR= 5.09) rather than under normal (BCR= - 0.42) and drought (BCR= -1.0) scenarios. These schemes need also effective methods of blue water saving under ANOR to re-allocate it under drought conditions and increase farming water supply. Yet, farmers tend to order more crop water requirements than their available water endowment for farming. They use inefficient cropping methods and water management techniques that significantly increase their farming water losses. Though GWC schemes may have high scale efficiency, their low cost, technical and allocative efficiencies under drought undermine their total economic efficiency.

Table 1: Economic efficiency and benefit-cost ratio of GWC schemes in Muooni Catchment

Scenario	Qty (m ³)	Water productivity	Total Cost Efficiency	Technical Efficiency	Allocative Efficiency	BCR
Flooding	12,702.7	6.98	0.049	2.773	0.018	5.09
Normal	5,202.31	78.93	0.213	0.132	1.613	- 0.42
Drought	7,942.08	68.06	0.453	0.010	0.453	-0.997

SOURCE: Luwesi, (2012)

Besides, the Willingness To Pay (WTP) of downstream farmers is inadequate for funding their upstream counterparts’ Willingness To Accept compensation (WTA) for their green water services. The inadequacy of their farming revenues explains

their inability to sustain their Payments for Watershed Services (PWS). Hence, the study concludes that the challenge facing any GWC in most ASATs is “to balance between a “priceless” natural economy that offers universal affordability of natural resources and an inflationary political economy that always rations poor ones in time of stress and scarcity. There is therefore need for creating efficient linkages between GWC schemes and BWS projects to enable agriculture keeping its limits under the Production Possibility Frontier (PPF)” (Luwesi, 2012).

Conclusion and Recommendations

Investments in GWCs are needed to increase the volume of accessible blue water in streams and lakes as well as groundwater, in order to foster a green revolution in the ASATs. This will mitigate impacts related to water disasters and crop failures, as well as alleviate farmers’ poverty. However, farmers little income and lack of benefits is a serious impediment to the economic efficiency and successful management of GWCs. The high cost of implementation of GWCs does not allow adequate Payments for Watershed Services (PWS) to upstream farmers, who are supposed to deliver services for catchment conservation. Yet, PES schemes, including GWCs, are designed to bridge this incentive gap so that green water service providers are compensated by blue water users for specified water management services. This is the great challenge facing GWCs in the ASATs of Kenya.

Therefore, farmers need technological innovations to increase water productivity and water use efficiency in agriculture. They also need to design water allocation plans to allot available water resources, and save excess rainwater lost during flooding to supplement water deficits during periods of droughts. This will enable them maintaining the actual crop water requirements under fluctuating rainfall regimes in the course of climate change. It is recommended that GWC schemes be merged with cost-effective BWS projects under conditions of drought to minimize deficits in water productivity and ensure higher Benefit-Cost Ratios (BCR). Such a practice shall be coupled with a fair pricing policy that will boost farming water profitability within the economic Production Possibility Frontiers (PPF). This policy shall be supported by both upstream and downstream farmers through a consensual agreement that will enable fair PWS for green water services delivery. Finally, these mechanisms need a backing from governmental agencies and development partners, not only for improving their technical innovation, but also for assuring their financial sustainability and economic feasibility. It is only under such conditions that GWS schemes would ensure agriculture and forestry sustainability in the ASATs of Kenya. Otherwise these schemes will remain technologically innovative and accepted by farmers but economically infeasible due to their inability to ensure cost recovery

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