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The Value of Green Water Management in Sub-Saharan Africa: A Review

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Abstract: Due to its multiple uses, water is a highly competed-for resource. While the competition is mainly in the use of the resource, contestation over water resources is also demonstrated through how the resource is defined and described. Terms such as water stress and water scarcity are commonly used in literature, and so are various colors that define water quality, including white, grey, yellow, and black water. Water that is useful for agriculture is distinctly known as blue or green water, with the latter increasingly gaining prominence in water planning for improved agricultural productivity. Proper management of green water has been shown to improve grain yields in Sub-Saharan Africa by as much as 2.5 – 6 times. The arid nature of Sub-Saharan Africa, coupled with the high evapotranspiration rates, calls for improved management of green water, including reducing evaporation losses, reducing seepage, and increasing the water holding capacity of soils. The value of green water management in Sub-Saharan Africa is further enhanced by its low-cost nature when compared to irrigation, which is an area that Sub-Saharan Africa has also been focusing on as part of the solutions to the increasing food needs of its growing population. Infrastructure for irrigation is costly and not affordable to the majority in Africa. In addition, irrigation can only benefit those communities near the water sources, whereas proper green water management can have benefits to all communities, including those far from a water source.

Keywords: *agricultural drought, meteorological drought, green water, blue water, green water grabbing, water scarcity, water stress*

Falkenmark (1995, 2008) introduced the term green water to describe the often unaccounted-for precipitation that goes into the root zone of plants. Green water is much needed in sub-humid and semi-arid regions where evapotranspiration rates are high and rainfall is generally low. As it is found buried in the soil, green water is also described as invisible water, while the visible flowing water is classified as blue water (Sood et al. 2014). Earlier definitions of green water continue to be refined; van der Zaag et al. (2002) define green water as rainfall that infiltrates the root zone and is used by plants for biomass production through transpiration, and Mekonnen and Hoekstra (2011) define it as rainwater that is consumed. Green water is also rainfall that infiltrates the soil and is picked up by roots before returning to the atmosphere as evapotranspiration (Falkenmark 2012). Hoekstra et al. (2011) added another layer to the definition of green water, referring to it as "water that is temporarily stored in the soil and on top of vegetation and returns to the atmosphere as evaporation instead of running off." Green water is useful for the sustenance of grazing pastures, forestry and other terrestrial ecosystems, and for crop production (Savenije 2000; Gerten et al. 2005).

The inclusion of green and blue water into the water mix is partly meant to improve water accounting and management, especially for water-scarce and water-stressed countries. In the semi-arid and sub-humid regions of Africa, the inclusion of green water brings a completely different picture to the region's water balance. Based on studies from Kenya, Falkenmark (2012) noted that

blue water accounts for only five percent of the country's water balance while green water, which forms the bulk 95 percent, is often not included in the country's water balance.

Unlike the temperate regions where annual evaporation rates are in the range of 100 – 500 mm, sub-tropical regions such as the savannas that make up much of Sub-Saharan Africa's sub-humid and semi-arid zones have annual evaporation rates as high as 2,000 mm, while as little as 100 mm is retained as blue water (Falkenmark 2012). The high evaporation rates in the sub-humid and semi-arid regions of the tropics imply that little of the received rainfall is available for crops and other terrestrial vegetation in the form of green water. Also, of the little rainfall that ends up as blue water, much of it flows out into surface water bodies including large rivers such as the Nile, Congo, Volta, and Zambezi Rivers, and lakes such as Victoria and Malawi. Africa has 64 large transboundary and lake basins (UNEP 2010).

In acknowledging the value of green water, countries are better placed to find ways of improving agricultural productivity, especially in sub-humid and semi-arid regions (Sood et al. 2014) like Sub-Saharan Africa's savannas. Referring to studies by the Stockholm International Water Institute, Falkenmark (2012) revealed the low agricultural productivity of green water in Sub-Saharan Africa. Based on farm field studies in semi-arid Nigeria, the Stockholm International Water Institute noted that as much as 90 percent of farm water needs came from rainfall, out of which only 12 percent was used by crops. As much as 70 percent of green water that could potentially reach the root system of crops evaporated from wet surfaces. The effect of the low uptake of water by crops through their roots was a reduction in potential grain yield from as high as seven tons per hectare to one ton per hectare. According to the study, a third of the 90 percent share of water received through rainfall was lost to runoff (Falkenmark 2012).

Falkenmark and Rockström (2006) observed that agricultural policies tend to focus on irrigated agriculture which uses only 25 percent of the global water. In their pioneering work on green water, Falkenmark and Rockström (2006) estimated that 5,000 km^3/year of water out of 6,800 km^3/year consumed in food production came from green water, implying a contribution of around 73.5 percent to the overall water budget. The balance came from irrigation. Unfortunately, Africa does not derive much benefit from irrigation due to low investment in the sector, while also suffering low uptake of green water as the farm studies from Nigeria by Falkenmark (2012) demonstrated.

This paper reaffirms that the generally arid conditions in Africa, coupled with the low capacity for further intensification of food production for a growing population, as well as low investment in infrastructure for irrigated agriculture, call for improved ways of managing and accounting for water. In addition, Sub-Saharan Africa's efforts for improved productivity of green water must adjust to the changing climate, as well as improve water use efficiency. The acknowledgement and proper management of green water is presented as one of the means for better water accounting and improved agricultural productivity. However, the paper also acknowledges the possible negative impacts of the horizontal expansion in the use of green water for agriculture through grabbing water from other ecosystems. Overall, the paper calls for the need to fully acknowledge green water as a valuable part in Sub-Saharan Africa's water mix.

Methods

This paper is largely based on the review of literature, with the intention of drawing answers to the meaning of green water and its role and value in water accounting and management in Sub-Saharan Africa. The paper also explains the role of green water in agricultural productivity in arid and semi-arid regions of Sub-Saharan Africa. The key question that the literature review seeks to address is, "What difference does green water make to agricultural productivity, especially in semi-arid and arid regions of Sub-Saharan Africa?"

Literature Review

With a total landmass of about 30 million square kilometers, Africa is the second largest continent in the world after Asia (UNEP 2016). There are 54 countries on the continent, with all but six located within the Sub-Saharan region. The six countries that are not in Sub-Saharan Africa are wholly or

partly in the Sahara Desert, and they are Algeria, Egypt, Libya, Morocco, Sudan, and Tunisia (Ekwe-Ekwe 2012). The Sahara Desert is the world's largest hot desert covering an area of 9.4 million square kilometres (Zimmermann 2012), translating to 31 percent of Africa's landmass. Other prominent deserts in Africa are the Kalahari and Namib Deserts, both located in the southern part of the continent. The large area covered by deserts in Africa, is partly the result of the dry conditions on the continent. According to the United Nations Environment Programme (UNEP 2010), Africa is the second driest continent in the world, with nine percent of global renewable water resources. The UNEP report also notes the uneven distribution of water in Africa, with as much as 50 percent of the internal renewable water resources being concentrated around the equatorial belt of the continent.

According to the United Nations Department of Economic and Social Affairs (UNDESA 2016), 66 percent of Africa is arid or semi-arid, and out of an estimated 1 billion people in Sub-Saharan Africa, close to 40 percent live in water-scarce environments where they live on less than 1,000 m^3 of water per capita per year. However, the use of water withdrawals upon which water scarcity has previously been defined is contested with scholars looking for a more comprehensive definition. For example, Hoekstra et al. (2012) suggested a measure of water use that includes consumptive use of both ground and surface water flows. This expanded definition of water scarcity would partly justify the need to acknowledge green water as this may correctly represent water availability, and in so doing allow for proper and more productive use of water.

Green Water and Agricultural Productivity in Sub-Saharan Africa

Green water is valuable for agricultural productivity, and therefore needs proper management, especially in arid and semi-arid regions. A United Nations Development Programme (UNDP) working paper (Chauvin et al. 2012) points to inadequate water and poor soil fertility as the main reasons for Africa's poor agricultural performance. Sub-Saharan Africa suffers chronic water stress, partly due to high population growth rates and urbanisation, as well as due to lack of infrastructure, especially for water harvesting. For example, out of the 980 large dams in Sub-Saharan Africa, 589 are in South Africa alone while Tanzania, which is of comparable size to South Africa, has only two large dams (Tatlock 2006). Very little of the continent's groundwater is tapped even though its quality is generally viewed to be good, however, little is known of the quantity (Pavelic et al. 2012). This implies that much of Africa relies on green water for its agriculture.

Throughout Sub-Saharan Africa, agriculture is a significant contributor to national economies. Agriculture's contribution to national gross domestic product (GDP) ranges from 3 percent in Botswana and South Africa to more than 50 percent in Chad (OECD and FAO 2016), while employing from low ratios of 5 – 10 percent in Angola, South Africa, and Mauritius to as much as 80 percent of total labor in Burundi, Burkina Faso, and Madagascar (Brookings Institute 2017). For the majority of countries in Sub-Saharan Africa, agriculture is the main source of exports. As a result, despite its supposedly water-stressed situation, Africa is a major exporter of virtual water, including Ghana's exports that are estimated at 12,151 Mm^3/year (Water Footprint Network 2016a) and Rwanda's virtual water exports of 233 Mm^3/year (Water Footprint Network 2016b).

Despite the significant socio-economic contribution of the agricultural sector, current efforts to increase productivity may not keep pace with the demands of a growing population which are not helped by the low investment in irrigation and the changing climate.

Growing Population

Africa's population is estimated at 1.27 billion, with Sub-Saharan Africa's share of the population pegged at 1.014 billion (Worldometer 2017). Sub-Saharan Africa has the world's fastest growing population which is expected to double by 2050, having increased from 507 million in 1990 to 936 million in 2013 (FAO 2015). The region is at the same time home to the largest proportion of food insecure people in the world, numbering 233 million people and representing one in every four persons said be undernourished (FAO 2014, 2016, 2017).

The growing population in Sub-Saharan Africa is part of the reason for the expansion of land under agriculture. Since 1995, the global cropland is estimated to have expanded by 68 million hectares, with Africa's share of the expansion estimated at 47 million hectares (FAO 2016). At that scale, Africa contributed almost 70 percent of the amount of new land that was brought into agriculture, with significant impacts on forests and biodiversity. The horizontal expansion of land under agriculture has meant a greater use of green water by farming at the expense of other ecosystems, a development called green water grabbing.

The growing population places increased demands for food, and this places further strain on water, including both green and blue water. Other socio-economic needs, such as energy, also exert pressure on water even though the water use by the energy sector is non-consumptive. According to Falkenmark and Rockström (2006), population growth places a significant increase in water requirements estimated at an additional 1,300 m^3 for every additional person per year. Part of this water is needed for food production.

Africa's growing middle class and its taste for diversified agricultural products such as vegetables, fruits, dairy, meat, and fish (NEPAD 2013) places greater demand on water and land, further straining the continent's water resources, including green water. According to Deloitte and Touche (2012), Africa's middle-class population increased from 111 million in 1980 to 313 million in 2010, representing a change in the ratio to total population of 26 percent in 1980 to 34 percent in 2010.

The implications of Africa's growing population, an expanding middle-class against a finite land resource, and the arid and sub-humid conditions, demand that the continent produces more food per unit area, and this includes the need to improve on green water productivity.

Investment in Irrigation

In 2006 Africa had 13.6 million hectares of irrigated land, an amount that had almost doubled from 7.4 million hectares over a period of close to 50 years (Lebdi 2016). Despite the expansion, the figure represented about 5.4 percent of Africa's arable land, and about 32 percent of the region's irrigated land potential of 42.5 million hectares (Lebdi 2016). The quoted figures indicate that Africa has close to 70 percent under-utilized potential for irrigated agriculture.

The biggest challenge to investment in irrigated agriculture is the high cost that is involved. Using year 2000 estimates, Lebdi (2016) noted that it costs Sub-Saharan Africa more than $8,000 in investment for one hectare of irrigated land where water is already available. Where a new water source is to be constructed (such as a dam) the unit cost per hectare is more than $14,000 and these high costs are prohibitive of large irrigation projects. Lebdi (2016) further observed that irrigated farming requires lots of water, with an area of 1,000 hectares having water requirements that are equal to the basic needs of two to three million people. Besides the high costs, Africa has never prioritized irrigation, but rather safe drinking water and sanitation (African Ministerial Conference on Water 2018).

The return on investment for irrigation is also considered low and not worthwhile for many initiatives in Africa where agriculture is largely for subsistence purposes. Drawing on studies from Kenya, Lebdi (2016) noted that the majority of small holder irrigation schemes in Sub-Saharan Africa are based on political rather than economic decisions. As such, some irrigation schemes are often not profitable, with only one in six assessed schemes in Kenya returning a net profit. While this conclusion could be confined to Kenya, it is worth noting that there are also expansive irrigation schemes across Africa, with the majority being for high value crops and are being run successfully by commercial enterprises. It is also worth noting that there are several small to medium scale irrigation schemes run by families and communities, with most of these being non-profitable (Barghouti and Moigne 1990).

The low investment in irrigated farming means a strong reliance on rain-fed agriculture in Sub-Saharan Africa, hence the importance of green water in food production in the region.

Changing Climate

The Intergovernmental Panel on Climate Change (IPCC 2014) identifies Africa as one of the most vulnerable regions in the world to the

impacts of the changing climate. Both the low and high emission scenarios project a warming Africa, and a decrease in rainfall in much of the continent with the exception of East Africa where rainfall is projected to increase (Serdeczny et al. 2015). Both climate change scenarios also project a more arid southern and southwestern Africa due to a decline in rainfall, while in parts of Somalia and Ethiopia wetter conditions are expected (Serdeczny et al. 2015).

The projected arid conditions across much of Africa may imply less reliance on rain-fed agriculture, but the continent's strong dependence on agriculture may call for more innovative ways of managing the scarce water resources, as well as on improving water productivity, including that of green water.

Water Use Efficiency

It is often argued that current agricultural practices, especially irrigated agriculture, are not efficient. Water use efficiency in irrigated agriculture is as low as 30 percent (Falkenmark and Rockström 2006). The situation is not different for rain-fed agriculture whereby 10 – 30 percent of seasonal rainfall is productively used as green water flow (Falkenmark and Rockström 2006), with as much as 50 percent being lost as non-productive evaporation, and 30 percent lost to runoff and ending up as blue water, while another portion is lost as deep percolation.

The level of water use efficiency is said to be lowest in the tropical rain-fed agricultural systems, with the largest of such inefficiencies being in the semi-arid and dry sub-humid zones or areas that are commonly known as savanna agro-ecosystems. According to Falkenmark and Rockström (2006), rain-fed agriculture in the savanna agro-ecosystems of Sub-Saharan Africa consumes between 2,000 – 3,000 m^3 of water on average for every ton of grain compared to the global average of 1,000 – 1,500 m^3/ton. The low water use efficiency in the savanna agro-ecosystems is due to low yields and high evaporation.

Water use efficiency, where green water is concerned, can be improved through better soil fertility management, soil tillage that allows for greater water filtration, and water harvesting. Pretty and Hine (2001) noted the possibility of doubling crop yields through improved methods of soil, crop, and water management, while Falkenmark and Rockström (2006) observed that integrated soil and water management has the potential to improve productivity in the savanna agro-ecosystems from the high of 3,000 m^3 per ton to 1,500 m^3 per ton.

Discussion and Conclusions

Green water, if properly accounted for and used in agriculture, is part of the long-term solutions to Africa's food security. The low average cereal yields of 1.6 ton per hectare compared to world averages of 3.9 tons per hectare (Tadele 2017) are partly blamed on poor management practices, including that of soil moisture and ultimately green water. The low yields are exacerbated by agricultural drought, which occurs when soil moisture is too low to sustain crop production and growth (Maracchi 2000). With better management and efficient use of green water, some high crop yields can be achieved. Management techniques that ensure proper retention of water will result in not only more productive use of green water, but also increased crop yields. The results below by Kauffman et al. (undated) followed some studies conducted in Africa:

- Mulching can reduce runoff by 72 percent, and this can increase rain water use efficiency by 20 percent;
- Good tillage practices can reduce runoff by 60 percent, and can increase rain water use efficiency by 58 percent; and
- Water conservation techniques can reduce runoff by 66 percent, resulting in as much as a three-fold increase in crop production.

The low rainfall amounts received in much of Sub-Saharan Africa, along with poor irrigation practices, call for improved management of green water. Proper management of green water will not only harvest as much rainfall as possible, but also ensure water conservation, limit evaporation losses, reduce seepage losses, improve efficiency in water use, and allow for the use of high water tables for farming purposes. With better management practices, inclusive of improved productivity of green water, average grain yields in Zambia were shown to increase from 1.3 tons per hectare to

4.5 tons per hectare (Mati and Hatibu undated). Such increases in the magnitude of 250 percent as recorded in Zambia and 600 percent in Nigeria make a good case for better understanding and use of green water in as far as this can significantly improve agricultural productivity. Additionally, the proper management of green water will not only cause higher crop yields, but also free up blue water for other uses, including hydropower generation, fisheries, and recreation. This is significant given that water is a much competed-for resource on the continent by domestic, industrial, and agricultural sectors.

In calling for improved management of green water, this paper also makes a case against expansion of land for agriculture. The common practice of horizontally expanding land for crop production not only causes loss of forests through land clearance, but also taps into green water for other terrestrial plant needs. Woodhouse (2012) warned that any rights to land also provide prior rights to water, implying that agricultural expansion is not just for the investments that are made on land, but also for all forms of expansion of agricultural land into natural forests. The horizontal expansion of crop fields not only means the substitution of the forest with crops, but also the grabbing of water by the newly crop-colonised land and from the replaced forest. In recent times Africa has become the priority region for large-scale land investments. While many scholars and policy makers have rightly described the investments as land grabs or land deals (African Union et al. 2013; Conigliani et al. 2016), water has often been the missing link. Even more misleading has been the narrow look at only blue water because it is harvestable and can be conveyed to places where it can be used. Much of the expansions and investments in large-scale land deals have also benefited from green water.

Large-scale investments in agriculture in Africa have emerged as a big business for the production of food, fuel, and fiber, as well as for conservation efforts. A report by UNEP (2016) shows that the continent has 60 percent of the world's unconverted arable land, indicating not only a great potential for local and external investment in food production on a massive scale, but also showing Africa's potential to become a major player in the global export of food, biofuels, and fiber. The importance of access to water in large-scale land investments is often underplayed and not recognized, although it is becoming clearer that water resources are a major attraction for such investments (Williams et al. 2012; Breu et al. 2016). Matavel et al. (2011) noted how sugar cane farming is linked to both land and water grabbing. While sugar production in Sub-Saharan Africa accounts for four percent of world production, there is huge potential for expansion of the crop area due to production potential, low cost of production, and nearness to the European markets (Tyler 2008). Due to the fact that new land may need to be opened up for sugar cane production, water will be grabbed from the replaced vegetation types and from the soil in general.

As green water is not included among the traditional water indicators, it is not surprising that it is often under-valued. This results in countries that are not water poor being classified as such, with implications for investment in agriculture and local food production. By stressing the importance of green water, this paper calls for not only the proper management and use of the resource, but also for the recognition of green water in water accounting.

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