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The Need for Agricultural Water Management in Sub-Saharan Africa

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Abstract

This paper discusses the current and future conditions that affect water resources and the constraints of water (agricultural) management in sub-Saharan Africa and suggests remedial measures to be considered by policy makers. The pressure on the quantity and quality of water resources is rising in sub-Saharan Africa due to the increased demand of water for agriculture and other purposes as a result of increase in population and food demand. The availability of water is also under threat from changing climate and as a result, water scarcity is expected in many countries in sub-Saharan Africa. On the other hand, the availability of water for agriculture is expected to further shrink due to the increasing demand of water for other purposes like industry, manufacturing and environmental requirement. The current poor efficiency rate of irrigation systems and massive expansion of irrigated area is expected to further exacerbate the water scarcity. Hence, a water management policy focused on maximization of water use efficiency and water productivity should be prioritized in order to meet the food demand of the growing population and cope with water scarcity problems. Engineering and management intervention integrated with strong society awareness and participation is considered very crucial in enhancing water use efficiency and crop water productivity.

Keywords

Water Scarcity, Water Management, Water Use Efficiency, Water Productivity, Sub-Saharan Africa

1. Introduction

World population has risen steadily from a total of 2.5 billion in 1950, to 7.4 billion in 2015 [1]. 16% of this

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growth comes from sub-Saharan Africa as the region has grown from 180 million to 962 million people from 1950 to 2015. This is about 12 million people a year for the past 65 years or approximately 782 million people in 65 years. According to the 2015 UN Revision, the current world population of 7.4 billion is expected to increase by 2.3 billion people within the next thirty five years, reaching 9.7 billion in 2050, and to further increase to 11.2 billion by 2100. Not surprisingly, by 2050 and 2100, the population of sub-Saharan Africa could be as large as 2.1 and 3.9 billion. This means 77% of the world population growth from 2015 to 2100 will be from sub-Saharan Africa.

This population growth would inevitably pose additional demand for food [2] [3]. As shown in **Figure 1** and **Figure 2**, majority of countries with higher population growth rate, for example, Ethiopia, Kenya, Uganda and Nigeria, are precisely those showing high level of undernourishment as a result of inadequate food consumption. Nonetheless, these countries are on the verge of development and the food consumption pattern is expected to increase in the near future. The high population growth rate coupled with increased per capita food consumption will highly increase the food demand of the region which cannot be fulfilled simply with the existing production level.

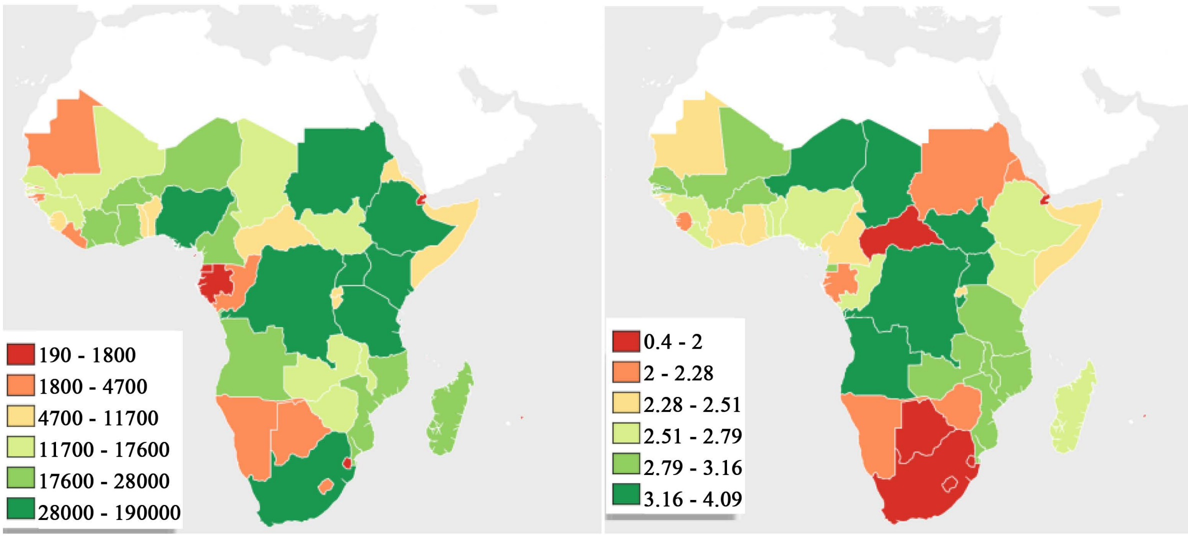

Figure 1. Total population (thousands) (left) and population growth rate (%) (right) in 2015 (source: United Nations) [1].

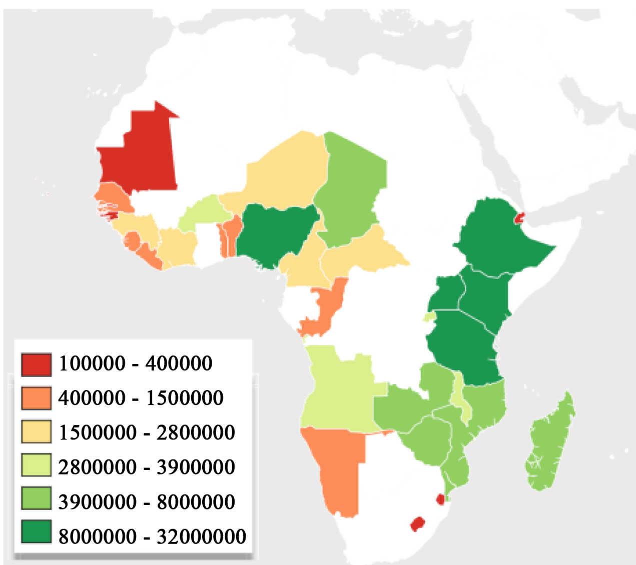

Figure 2. Number of people who are undernourished in 2015 (Source: World Bank [4]).

In sub-Saharan Africa, food consumption of cereals such as maize, millet, sorghum, and teff (in Ethiopia) is the mainstay of diets [4]. As presented in **Table 1**, the demand for cereals is higher than the production in many

Table 1. Food (cereals) production and consumption in sub-Saharan Africa (Source: FAO food security data by food groups/items, June 2012).

Country	Production (kg/person/year)			Consumption (Kg/person/Year)			Deficit		
	1997	2002	2007	1997	2002	2007	1997	2002	2007
Angola	32	41	45	59.9	72.3	81.0	−27.9	−31.3	−36.0
Benin	130	136	130	108.0	104.0	116.1	22.0	32.0	13.9
Botswana	42	16	18	123.7	109.5	109.5	−81.7	−93.5	−91.5
Burkina Faso	215	233	242	223.7	219.7	233.6	−8.7	13.3	8.4
Burundi	43	37	35	30.3	28.8	35.8	12.7	8.2	−0.8
Cameroon	86	84	95	89.4	96.7	108.8	−3.4	−12.7	−13.8
CAR	35	45	53	41.6	48.9	57.3	−6.6	−3.9	−4.3
Chad	121	128	181	108.8	118.3	144.5	12.2	9.7	36.5
Congo	4	5	6	44.2	75.2	77.0	−40.2	−70.2	−71.0
Comoros	24	21	21	74.5	74.5	75.2	−50.5	−53.5	−54.2
DRC	30	27	23	34.7	32.9	39.8	−4.7	−5.9	−16.8
Djibouti	0	0	0	111.3	125.9	138.7	−111.3	−125.9	−138.7
Eritrea	31	31	74	127.8	120.8	134.0	−96.8	−89.8	−60.0
Ethiopia	145	132	168	123.0	138.3	142.7	22.0	−6.3	25.3
Gabon	25	20	23	94.2	101.8	109.5	−69.2	−81.8	−86.5
Gambia	85	120	117	139.8	142.7	147.5	−54.8	−22.7	−30.5
Ghana	95	87	81	82.5	87.6	97.5	12.5	−0.6	−16.5
Guinea	143	167	212	127.4	127.0	127.0	15.6	40.0	85.0
Kenya	101	93	100	120.1	117.5	120.5	−19.1	−24.5	−20.5
Lesotho	103	97	52	216.8	221.9	227.4	−113.8	−124.9	−175.4
Liberia	34	33	35	97.8	89.1	97.5	−63.8	−56.1	−62.5
Madagascar	137	121	145	111.7	117.9	129.6	25.3	3.1	15.4
Malawi	164	167	177	147.8	142.4	143.1	16.2	24.7	33.9
Mali	205	205	274	181.0	187.6	199.7	24.0	17.4	74.3
Mauritania	78	43	50	164.3	159.5	169.0	−86.3	−116.5	−119.0
Mauritius	0	0	1	152.2	155.1	161.0	−152.2	−155.1	−160.0
Mozambique	79	76	66	91.6	92.7	101.5	−12.6	−16.7	−35.5
Niger	207	247	281	200.0	201.1	197.5	7.0	45.9	83.5
Nigeria	185	156	181	136.9	133.6	145.6	48.1	22.4	35.4
Rwanda	31	33	39	33.9	32.1	43.4	−2.9	0.9	−4.4
Senegal	100	87	86	154.0	152.6	164.3	−54.0	−65.6	−78.3
Sierra Leone	78	54	136	107.3	113.2	112.1	−29.3	−59.2	23.9
Sudan	134	115	157	138.3	123.0	130.7	−4.3	−8.0	26.3
Swaziland	138	81	50	133.6	124.1	127.8	4.4	−43.1	−77.8
Tanzania	132	130	133	106.2	106.9	104.0	25.8	23.1	29.0
Togo	142	141	137	116.1	118.6	123.7	25.9	22.4	13.3
Uganda	80	88	84	59.5	58.8	63.5	20.5	29.2	20.5
Zambia	127	90	116	157.3	142.0	136.9	−30.3	−52.0	−20.9
Zimbabwe	192	141	120	148.6	144.5	157.0	43.4	−3.5	−37.0
South Africa	272	280	227	178.5	186.2	186.9	93.5	93.9	40.1
Namibia	68	59	64	130.7	132.1	131.4	−62.7	−73.1	−67.4
Côte d'Ivoire	70	62	58	96.0	89.4	93.4	−26.0	−27.4	−35.4
Guinea-Bissau	111	99	113	139.4	146.7	146.7	−28.4	−47.7	−33.7

of the sub-Saharan Africa countries. The gap between production and consumption would be more pronounced if other food groups, like starchy roots, vegetables, meat, egg, and others, are considered. To fill this gap and ensure food security dramatic increase in agricultural production is inevitable.

Approximately 40% of the world's food comes from 17% of the world's cropland that is irrigated which consumes more than two-third of the world's developed water supplies [5]-[8]. The increase in population and the food demand as well as the changing consumption patterns toward a higher nutrition will be posing challenges to agricultural production [9]. A FAO analysis [10] of 93 developing countries expects agricultural production to increase over the period 1998-2030 by 49% in rain fed systems and by 81% in irrigated systems. According to World Bank [4], agricultural production could nearly triple in sub-Saharan Africa by 2050. In this regard, arable land expansion will remain an important factor in the growth of crop production in the region. In developing countries, it is expected to observe a projected net increase in the arable area of some 107 million ha (from 968 in 2005/07 to 1075 in 2050) of which the 51 million (48%) is expected to take place in sub-Saharan Africa [4].

In sub-Saharan Africa, the water use efficiency estimated for the year 2005/07 and projected for the year 2050 is 22 and 25 percent respectively, which is by far less than the world average which is 44 and 46 percent respectively [11]. Although, the current water withdrawal for agriculture and other purposes is lower than the total annual renewable water resource, this low water use efficiency will undoubtedly challenge the sustainable use and management of water in the region. Thus, expanding the irrigated area under the present agricultural water management characterized with low irrigation efficiency rates will result in severe water scarcity in the coming decades.

From **Figure 3**, it is clear that countries with larger total renewable water resources are also having a huge population, resulting in a lower total per capita water availability. In 2014, 16 SSA countries were already under water stress, water scarcity and absolute scarcity conditions according to the "*Falkenmark indicator*" or "*water stress index*". Based on the per capita usage, the water conditions in an area can be categorized as: no stress (> 1700 m^3 per capita), stress (1000 - 1700 m^3 per capita), scarcity (500 - 1000 m^3 per capita), and absolute scarcity (<500 m^3 per capita) [12]. As shown in **Table 2**, the per capita renewable water resource was declining with time due to the increase in population. As predicted by Falkenmark [13], most of the East and some of the South African countries have already been water stressed. The projection by Falkenmark [13] indicates that eight of the East and some of the South African countries will arrived at absolute scarcity by 2025 and five of the West African countries will become at least water stressed in the early decades of the twenty first century.

Not surprisingly, the water resources of some countries had already been declined and changed from no stress to stress and scarcity levels. For instance, in 2007, Comoros, Nigeria and Uganda were under no stress condition. However, in 2012 and 2014, their water resource was declined and changed to the stress category. Similarly,

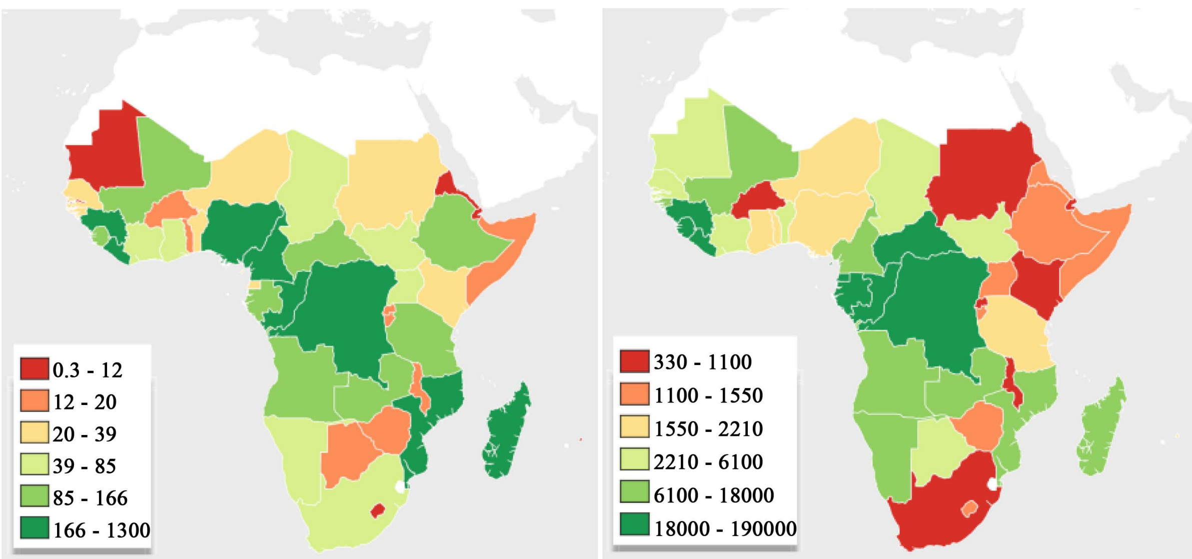

Figure 3. Total renewable water resources, BCM, (left) and total renewable water resources per capita, m^3/person/yr, (right) in 2014 (Source: FAO Aquastat 2015).

Table 2. Per capita renewable water resources (Source: FAO Aquastat 2015).

Country	Water resources (m^3/per/yr)		
	2007	2012	2014
Djibouti	375.50	348.80	339
Kenya	813.20	711.00	674
Burkina Faso	948.40	820.20	775
South Africa	1035.00	980.20	966
Malawi	1260.00	1086.00	1027
Sudan	No data	1016.00	975
Rwanda	1340.00	1161.00	1099
Eritrea	1404.00	1193.00	1119
Burundi	1506.00	1273.00	1196
Ethiopia	1517.00	1330.00	1264
Lesotho	1545.00	1473.00	1440
Zimbabwe	1570.00	1457.00	1370
Somalia	1650.00	1442.00	1360
Comoros	1896.00	1671.00	1596.00
Nigeria	1944.00	1695.00	1603.00
Uganda	1956.00	1654.00	1547.00

South Africa's water resources status was changed from stress category in 2007 to scarcity category in 2014. Nevertheless, the attention given to water management in sub-Saharan Africa is still inadequate. As a result, over exploitation of water resources by different sectors is shadowing the efforts made to ensure sustainable water use in the region. Considering the global figure, withdrawal of water by about a quarter of the irrigated systems is above the regeneration rate [14]. This coupled with the poor property rights specifications on water resources and inefficient irrigation practices is creating a potential for serious water shortages. Moreover, with the growing demand of water for industry, manufacturing and urban sectors, combined with environmental problems, water available for agriculture will decrease in the future [15]-[18]. On the other hand, as irrigation (agriculture) is vitally important in meeting the food and fiber needs for a rapidly expanding world population, the demand for agricultural water is continuously growing [3] [7] [19]. Additionally, the rapid growth in population and income requires large water investments and financing that result in further pressure on the quantity and quality of water resources [20]. The problem of providing the food for a much greater world population, therefore, becomes focused on the area of growing more on existing water and land resources [21].

2. What Are the Areas of Improvement in Water Management?

Many sub-Saharan Africa countries must develop more than twice the amount of water they currently use to meet reasonable future requirements [21]. For instance, Ethiopia must double its cereal production by 2025 to meet the food needs of its rapidly growing population and secure food self sufficiency which in its turn escalate its agricultural water demand [22]. Considering the fact that 90% of staple food for sub Saharan Africa comes from rain-fed farming systems, [23] cited in [24] recommended that much greater emphasis will have to be given to increasing the productivity of global rain-fed agriculture. However, rain-fed agriculture remains risky because of spatial and temporal variability in rainfall, water scarcity, droughts, soil erosion by wind and water, low investment, or high population pressure [25]. Moreover, there is a significant difference in crop yields between irrigated and rain-fed agriculture. In developing countries, grain yields from rain-fed agriculture are 1.5 t/ha compared to 3.1 t/ha from irrigated agriculture on average [26] cited in [9]. Hence, due attention will have to be given to better management of water resources in both irrigated and rain-fed agriculture. In this regard, instead of trying to supply the growing demand for water with new sources, improvement in the water-use efficiency should be the main focus in water-management policies [18] [27]. To increase water-use efficiency, several practices can be adopted. Water-saving techniques, advances in irrigation technology (e.g., drip irrigation) and management, leaving crop residues on the soil surface and planting cover crops and adequate tillage practices are considered as potential measures to improve water use efficiency and adapt to climate change impacts [9] [28]-[30]. However, with the limited and shrinking water availability, the increasing water requirement, due to expansion of irrigable lands as a result of growing population and food demand, cannot be reversed by improving the water use efficiency only. Hence, increasing water productivity deserves much attention as well. Increasing water productivity means either to produce the same yield with less water resources or to obtain higher crop yields with the same water resources [31] which would enable growing more food and hence feeding the ever increasing population or gaining more benefits with less water [32]. In its broadest sense, it reflects the objectives of producing more food, income, livelihood and ecological benefits at less social and environmental cost per unit of water consumed [33].

Sub-Saharan Africa countries, often characterized with low yield levels and large on-farm water losses resulting in poor water use efficiencies, have a promising potential for improvements in water productivity through introduction of agronomic or engineering measures [15] [33]. An important means of achieving increased water productivity will be to get more from the amount of water that is beneficially depleted by agriculture which can be achieved by introducing different agronomic, engineering and management technologies such as changing crop varieties, crop substitution, deficit, supplemental or precision irrigation [7] [16]. The next sections discuss small holder drip irrigation and water pricing as examples of the engineering and management techniques to improve water productivity and, of course, water use efficiency.

2.1. Small Holder Drip Irrigation System

Drip irrigation's combination of water savings and yield increases typically produces at least a doubling of water productivity, yield per unit water, and makes it a leading technology in the global challenge of boosting crop production in the face of serious water constraints [34] cited in [35]. However, due to its high capital cost, particularly for the poor farmers, the conventional drip irrigation is generally not widely used on a global scale and accounts for less than 0.1% of irrigated land worldwide [36]. Nonetheless, smallholders drip irrigation system attempts to retain the benefits of conventional systems while removing the factors that prevent their adoption by poor smallholders: purchase cost, the need for a pressurized supply, the associated pumping costs, and the complexity of operation and maintenance. It can help solve water management problems faced by smallholder farmers by making it easier and simpler to supply the right amount of water to their crops at the right place and at the right time [37]. Drip irrigation used about 35% of the water used by the surface irrigation systems thus giving much higher water use efficiencies [38]. It was also concluded by [38] that low cost drip systems achieved water saving of more than 50% compared to surface irrigation systems. Further results from field trials demonstrate that affordable smallholders drip systems easily pay for themselves in one growing season, and stimulate shifts to more intensive agricultural practices by small farmers [39]. Implementation of this technology might help improve livelihoods of individual farmers or small communities and is mentioned promising in the context of poverty alleviation which is the number one enemy of many sub-Saharan Africa countries [36].

Despite the higher potential for smallholder drip irrigation and other small scale irrigation technologies as supplementary irrigation for millions of people and to achieve household food security, the use of the technology has hardly begun in many sub-Saharan Africa countries. With proper marketing and proper agronomic and technical support low cost irrigation technologies can be adopted by smallholder farmers to change family lifestyles, increase people's incomes, create employment and go a long way towards food security and improved nutrition [38]. However, recent literatures argue that the success of the technology is interpreted through development agencies lenses and with the intention of continuing involvement in future projects [40] [41]. Hence, it is recommended to get the technology tested for its efficiency, productivity and social acceptance by farmers and independent researchers before its introduction and distribution to the vast agrarian population.

2.2. Water Pricing

Water pricing has become a key issue in both the developed and developing world. It is designed taking into account various objectives which are oftentimes more and more difficult to achieve due to environmental constraints, increased water demand, climate change and economic crisis which impacts all incomes (households, farmers, industries). The three main objectives of water pricing are balancing water budget, allowing water access, and inciting users to save water [42]. Achieving these objectives directly leads to a better water resource management which could help us in coping with the scarce and still shrinking water resource. [20] reported that pricing of water and water services are an acceptable practice that may result in better conservation and sustainable management of water. This is because higher prices for water use would encourage its more rational use by agricultural users and provide funds for investing in infrastructure which are two necessary conditions to avoid risk of water shortage [43].

Although, water pricing has long been practiced in some developed countries, it has been rarely or hardly implemented in sub Saharan Africa. The question here would be "how to introduce water pricing for the first time in an area where water has been accessed for free?" and "on what basis to effect the pricing?". In principle, there are multiple pricing patterns for irrigation water. The most common pricing systems are based on volume, area, electricity consumption (for groundwater based irrigation), type of irrigation or crop and block rate pricing structure [44]. The experience of the countries which have already implemented different pricing systems can be taken as a bench mark to choose better pricing approach in a particular area. The area pricing system, modified according to the crop or irrigation techniques, does not encourage water saving for a given choice of crop or irrigation technique, but it does have more effect on the choice of which crops to irrigate or which irrigation technique to adopt [45]. Pricing systems based on volume, volumetric pricing, and block rate pricing structure are known for their effect on high water savings. [46] cited in [47] estimated a 40% reduction in irrigation water demand associated with the increasing block rate structure.

Water pricing alone will not always be a sufficient incentive for users to enhance water saving and improve irrigation performance [45]. Thus, due consideration is needed to be given to water distribution and control. Rational water use has to be achieved by careful control of distribution and by allocations that broadly meet crop requirements. In this regard, it is required to enhance understanding of water scarcity among irrigators and encourage more efficient water use. It is also worthy to ensure better control over the supply of water as it can reduce wastage of water associated with excess amounts of water flowing through uncontrolled canals and ungated turnouts onto fields and into drainage channels [48].

3. Conclusion

Water scarcity is becoming severe and the availability of water for agriculture is dwindling due to increasing population and food demand, changing climate, expansion of industries and manufacturing. In order to sustain their economy and feed their population, sub-Saharan Africa countries should implement sound, feasible and implementable water management policy that can help in obtaining more production from the existing resources, land and water, through maximization of water use efficiency and crop water productivity. It is, thus, wise to develop a set of engineering and management interventions such as water-saving techniques, improved irrigation management, supplemental or precision irrigation, water pricing and better agronomy. Before implementation, however, the intervention measure should be tested through independent and participatory research. Above all, farmers, government and non-governmental organizations should cautiously evaluate the feasibility of the intervention measures and proper awareness should be given to the farming community.

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