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IRRIGATION AND ON-FARM WATER MANAGEMENT IN ETHIOPIA AND SOUTH SUDAN

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REHABILITATION AND MANAGEMENT OF SALT-AFFECTED SOILS TO IMPROVE AGRICULTURAL PRODUCTIVITY (RAMSAP) IN ETHIOPIA AND SOUTH SUDAN

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Rehabilitation and management of salt-affected soils to improve
agricultural productivity in Ethiopia and South Sudan

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EXECUTIVE SUMMARY

This report discusses the water resources and irrigation development situations in Ethiopia and South Sudan. Agriculture is an important economic sector in Ethiopia, accounting for about 80% employment, 43% of the GDP, and 75% of export values. Ethiopia has an estimated 50-70 million ha arable land, of which only 15 million ha is currently cultivated. The agriculture in Ethiopia is dominated by small-holder farmers depending mainly on rainfed production systems that are less productive and susceptible to climate shocks. The country has a surface water potential of about 124 Bm3 with large spatial and temporal variability. Despite these extensive resources, Ethiopia has exploited only a little of its water resources for its socio-economic development due to multiple constraints.

Irrigation development is a critical enabling intervention for increasing agricultural productivity, ensuring food security, and alleviating poverty. The physical irrigation potential of Ethiopia is estimated from 7.5 - 11 million ha. Currently, only 1.2 million ha is irrigated. Largely inefficient surface irrigation methods dominate the irrigation practices in Ethiopia, accounting for about 98% of irrigated areas, while sprinkler and drip account for only 2%. Overall average irrigation efficiencies in significant irrigation schemes in Ethiopia range from 30-50%. The sustainability rate of developed irrigation schemes in Ethiopia is meager; for instance, only 40% of the planned areas are irrigated for large and medium-scale irrigation schemes. Although several socio-technical factors are responsible for the reduction in irrigated areas, increasing soil salinity and sodicity are among the major ones.

Several factors constrain irrigation development in Ethiopia. These include budget constraints, limited private sector involvement, technical capacity limitations, insufficient irrigation infrastructure, socio-economic conditions such as resettlement, land redistribution, etc. On the other hand, the temporal and spatial variability of the water resources is also an additional constraint to irrigation development. In more recent national development plans, however, irrigation development is given high priority. As a result, the budget allocated to the sector has increased by several folds in a few years, which is an excellent opportunity for the sector's development. Government funding has remained to be a significant source of finance for irrigation development. However, the government has prepared a plan to enhance the participation of the private sector in irrigation development and management.

Soil salinity in irrigated lands is a widespread land degradation problem in Ethiopia, hindering irrigated agriculture productivity. Due to inadequate irrigation practices, salinity has affected the productivity of several irrigation schemes, particularly in the Awash and Rift Valley Lakes Basins. Significant portions of irrigated lands in the major irrigation schemes in the Awash Basin have been abandoned, mainly due to salinity, among others. The salinity risks in irrigated lands are primarily associated with inefficient flood irrigation systems, lack of drainage facilities, and irrigation with marginal quality water

Due to inefficient irrigation, rising groundwater levels are evident in several major irrigation schemes aggravating the problem of soil salinization. The proven techniques for irrigation water management under saline conditions include ridge planting, leaching, adopting more frequent irrigation, improving localized (drip) irrigation whenever suitable to leach out salts from the root concentration areas, and pre-plant irrigation. In general, irrigation water management practices in Ethiopia give little or no attention to techniques to reduce soil salinity, causing a huge price to be paid to the loss of irrigated lands. It is, therefore, time for all actors in irrigation development and management to take account of the risks and take all the required measures to ensure sustainable irrigated agriculture under saline conditions in Ethiopia.

South Sudan has a substantial amount of surface and groundwater resources. The country's annual renewable surface and groundwater resources are estimated at 26 and 4 Bm^3, respectively. The internal renewable water resource comprises the Nile river system and the Rift Valley basin. The primary groundwater formation in South Sudan is the Sudd basin, also known as the Umm Rwaba basin, which comprises lakes and swamps, marshes, and flood plains.

Despite rich water resources present in the country, only 5% of the total area is irrigated due to a lack of irrigation infrastructure. The irrigated land in South Sudan is estimated at 1.5 million ha is divided between the Nile-Sobat river basin, the Western and Eastern Flood Plains, the Mangala region the Green Belt zone. Several plans for irrigation development in Southern Sudan were prepared in the 1970s and 1980s; however, because of the instability, these plans were not implemented and are still essentially non-functional. The current area under irrigation is only 38,100 ha, and irrigation mainly uses surface irrigation methods with 30-35% efficiencies.

There are also critical environmental concerns in South Sudan related to water resources and their management. Water levels in rivers decrease due to increased erosion and siltation caused by land-use changes and overexploitation: forest clearing, over-grazing, and fires. Former permanent rivers are becoming seasonal. A drop in the groundwater table is also observed in Northern Bahr el Ghazal State. Decreasing rainfall, attributed to local environmental changes and climate change, might also explain groundwater level drops. Furthermore, salinity issues in the groundwater around Malakal and isolated villages and water pollution from industrial oil wastes in Unity and Upper Nile states.

Currently, South Sudan's water sector is also impaired by a lack of updated data and information for surface water and groundwater resources. No formal system for allocating water resources to sector or user exists, apart from customary laws. Intense competition for water in the dry season often leads to disputes between farmers and pastoralists, who travel long distances depending on water availability. Several initiatives need to be taken to strengthen the agricultural sector to achieve maximum benefits from irrigation development. These may include increased access to fertilizer, provision of extensive extension services, increased adaptive research facilities, enhanced private investment, increased agricultural mechanization, and modification of land-tenure laws.

01

ETHIOPIA

Ethiopia is one of the 11 East-African countries, including Kenya, Tanzania, Uganda, Djibouti, Ethiopia, Eritrea, Somalia, Rwanda, Burundi, South Sudan, and Sudan (Figure 1). This region has a complex and diverse climate ranging from hot, arid, and semi-arid in most Djibouti, Eritrea, Somalia, and Sudan and the eastern half of Ethiopia and Kenya to tropical rains in western Ethiopia and Kenya, South Sudan, and Uganda. Mean annual rainfall varies from over 2,000mm in southwestern Ethiopia to below 250mm in the arid areas of Djibouti, Kenya, and Somalia. Kenya, Somalia, Uganda, southern and southeastern Ethiopia, Rwanda, and Burundi have bimodal rainfall regimes. In contrast, Sudan, South Sudan, Ethiopia, and Eritrea have one primary rainfall season – from June to September, with the peak intensity in July and August. The average annual rainfall is enough to ensure sustainable agricultural production in the region. However, the actual performance of the agriculture sector is below potential in nearly all the countries, and periodic crop failures are common.

The region's annual renewable water resources (surface water and groundwater) are estimated at 187 km3 (UNDP, 2000), whereas yearly freshwater withdrawals are a small percentage of the total available water. The annual per capita renewable water resources ranged from water vulnerability (1,700-2,500 m3) in Uganda and Tanzania to water scarcity (500-1,000 m3) in Kenya and South Sudan (UN-Water, 2015). All other Eastern African countries are defined as water-stressed (1,000-1,700 m3).

Figure 1. Map of Eastern-Africal countries

Djibouti, Eritrea, Ethiopia, Somalia, and Kenya belong to one of the world's most vulnerable drought-prone regions, where subsistence smallholder rainfed agriculture dominates. The vulnerability of agriculture is strongly related to the unreliability of rainfall. Only 5% of the region's total cultivated area is irrigated compared to 37% in Asia and 14% in Latin America (You et al., 2010). This shows that Africa is far from achieving its irrigation potential, estimated at 42.5 million ha (FAO, 2015).

Ethiopia is a landlocked country located between the latitudes 5°N and 15°N and longitudes 35°E and 45°E. Six countries border the country, Eritrea in the North, Djibouti and Somalia in the East, Kenya, and Somalia in the South, and Sudan and South Sudan in the West. Ethiopia's population is estimated at 100 million and is the second-most populous country in Africa, next to Nigeria (UNDESA, 2015). Most of the population lives in rural areas, and agriculture is the backbone of the country's economy. Agriculture directly supports about 85 % of employment and livelihood of the people; contributes about 50 % of the country's GDP; generates about 88% of the export earnings and supplies around 73% of the raw materials required by domestic agro-based industries (Deressa, 2007).

Ethiopia is one of the largest countries in Africa, covering 112 Mha, of which 36% is arable land (Awulachew, 2010; FAO, 2014). Currently, 15 Mha (40%) of the agricultural land is under cultivation, primarily located in the highlands (1500masl) (Awulachew, 2010). High population growth and increasing demand for agricultural land have resulted in the massive deforestation of natural forests. Extensive use of lands without proper management has caused excessive land fragmentation and severe soil degradation. Ethiopian highlands' per capita land area has fallen from 0.5 ha to 0.2 ha over the last two decades. The vast fertile and uncultivated lands are located in the arid and semi-arid lowlands of the country. However, due to erratic rainfall distribution, droughts have become a permanent feature of these areas, making irrigation necessary for sustainable agricultural production.

In the case of Ethiopia, out of 5.3 million hectares (Mha) of potentially irrigable land, only 700,000 ha is currently equipped for irrigation (Dejene, 2015). Recently, Ethiopia has been investing heavily in large-scale irrigation schemes both for commercial and food crops. In South Sudan, the irrigated area is only 38,000 ha from a total of 1.5 Mha of cultivable land that could potentially be brought under irrigation (AfDB, 2013). Therefore the provision of irrigation can play an essential role in boosting agricultural productivity in the region.

The slow irrigation expansion in Africa is linked to high costs and poor participation of farmers. The average irrigation development cost in the world is US$4,800/ha compared to US$13,000/ha for Africa in general and US$18,000/ha for Sub-Saharan Africa in particular. The rehabilitation cost of irrigation schemes was estimated at US$8,200/ha in Africa against US$2,300/ha anywhere else (Ofosu, 2011). African farmers are also reluctant to invest in irrigation schemes because of land tenure and ownership issues (Subijanto et al., 2013). Few African countries have tried to recover capital costs from users. In contrast, others consider the development and operation of irrigation schemes as welfare projects and do not charge any expenses to farmers. Cost recovery for operation and maintenance of irrigation schemes is critical to avoid the built-neglect-rebuild and neglect syndrome in Africa, where national governments have severe financial constraints.

Experiences from Asia indicate that the sustainability of irrigation schemes is sure where the capital costs of irrigation schemes are recovered from the beneficiary farmers (Svendsen, 2009). Experiences in the smallholder irrigation schemes in Southeast Asia proved that poor farmers have been willing and able to invest considerable amounts of money for irrigation projects. The involvement of farmers (through the establishment of Water User Associations) in the irrigation schemes in Pakistan, Mexico, and many other countries has proven effective in collecting water charges, equitable water distribution among different users, and sustainable operation and maintenance.

The predominant agricultural systems in Ethiopia are characterized by rainfed and extensive crop and pastoral systems. The crop yields are well below their productive potential due to deficient use of fertilizers, lack of access to irrigation water, and low water use efficiencies (Tittonell and Giller, 2012). The water use efficiencies are about 25%, half of the world average of 45% (Bruinsma, 2009). This suggests that achieving sustainable food security in Ethiopia will remain a challenge without transition from traditional rainfed agricultural systems to intensive irrigated agriculture. This requires concerted efforts by the national governments to designate more capital and resources to establish small-scale and large-scale irrigation schemes.

Farmers also need training about water-saving strategies. The impact of climate change on crop yields and its socio-economic repercussions is another significant concern, especially in light of the region's high dependence on rainfed agriculture. This report reviews the current water resources management practices in Ethiopia and South Sudan to identify technological and policy gaps and suggest potential measures that can help in improving water resources management and efficiency of water use in agriculture. The report also discusses policy recommendations and institutional arrangements that can help ensure sustainable water resources management in both countries.

02

IRRIGATION SCHEMES IN ETHIOPIA

2.1 Traditional irrigation schemes

Ethiopia is known as the water tower of Africa for its peculiar geomorphologic and climatic settings. No drainage comes into the country but flows out from the highlands and midlands towards the arid and semi-arid lowlands. Generally, 40% of the country's land is a recharge area with surplus rainfall, flowing untouched through the surroundings (Alemayehu 2008; van Steenbergen et al., 2011). The arid and semi-arid lands constitute 60% of the country's surface area with highly variable and unpredictable rainfall. The radial flow from the high and middle parts of the country can be captured through proper management before entering into the detached deep valleys. The arid and semi-arid lowlands consist of fertile alluvial plains. They can be irrigated using the runoff flowing across these plains through spate irrigation by making diversion canals of different scales.

The history of diverting flood and runoff water for irrigation in Ethiopia dates back to the pre-Axumite period (560 BC) (Alemayehu 2008; Mehari et al., 2010). Traditional irrigation practices in Ethiopia started more than a millennium ago. However, large-scale irrigation development began in the 1950s in the Awash Basin, Ethiopia's most developed river basin, to cultivate sugarcane and cotton crops. The first irrigation schemes Wonji-Shoa and Metahara were authorized in 1954 and 1965 to irrigate 5,000 ha and 11,000 ha of sugarcane, respectively (Gebul, 2021). Between 1960-1980, irrigation schemes, notably Merti, Jeju, and Amibara, were developed mainly for cotton production.

In ancient times, highlands farmers used traditional techniques to divert streams to irrigate their small plots for producing vegetables and spices (Bekele et al., 2012). Supplementary irrigation has also been practiced for subsistence farming. Spate irrigation through the diversion of runoff water has traditionally been practiced in Eastern Amhara, Southern Tigray, and Eastern Oromia. Vernacular names of spate irrigation differ from place to place, but generally, it is referred to using seasonal floods to compensate for rainfall shortages that could have affected seasonal harvests. For example, in south-eastern parts of Ethiopia, 'Gelcha' or 'Lola Debesuu' is used for spate irrigation with a literal meaning of 'divert the flood into the farm.' Spate irrigation is commonly called 'Telefa' ('diversion') in the northern parts. Typically, there are two systems of spate irrigation: wadi-bed and off-wadi systems (Oweis et al., 2012). The wadi-bed is used to store water either on the surface by blocking its flow or reducing the flow speed to allow water infiltration in the soil profile. The flood is forced out of its natural course to nearby areas suitable for agriculture in the off-wadi system.

Currently, the spate irrigation area has reached 140,000 ha (Erkossa et al., 2014). In the eastern parts of the country, farm runoff is collected in small embankment gullies, and the ponded water is used for irrigating valuable perennial crops, i.e., "khat" (Catha edulis), coffee (Coffea arabica L.), and fruit trees. Use of seasonal floods originating from eastern highlands and ending up in the lowlands has long been practiced in the Dire Dawa area. Farmers establish simple diversion canals using wooden trash and soil materials to divert floodwater into their farms. Similar practices in northern and northeastern Ethiopia include Alamata in Tigray, Kobo in Amhara, and Aba'ala in Afar (Erkossa et al., 2014). The spate irrigation practice in the Gato Valley in North Omo of southern Ethiopia also includes ridge ties to retain moisture in the soils around the plant roots. Similarly, in Konso, Gidole, and many other south Ethiopia, farmers use bench terraces and trash lines for in-situ water conservation on their cultivated lands (Alemayehu 2008: van Steenbergen et al. 2011). In addition to diverting seasonal flows into farms, farmers in some areas also use water harvesting and groundwater recharging techniques such as ponds and shallow groundwater reserves to irrigate their farms.

Almost all traditional irrigation systems in Ethiopia are managed by farmers and are small scale in size. Infrastructural upgrading of these systems is done mainly by local governments and in limited cases by NGOs with labor and material contribution from user communities. Communities handle operation and maintenance. Local governments and NGOs offer occasional support when costs and damages are beyond the capacity of communities.

In improved spate irrigation systems, floodwater is distributed to individual fields followed by field to field supplies where users are organized in water user associations (WUAs). Extensive distributions are not common as most spate irrigation systems are limited in size. Typically irrigation starts from upstream users and is fairly distributed to downstream users. However, in most spate irrigation areas, the practice begins from the most moisture-stressed downstream users. As the spate expands upstream, the rights of downstream users are protected by leaders of the minor administrative units, community elders, and WUAs. Total coverage of plots is the minimum requirement; the depth varies depending on the frequency and quantity of flood. In most spate irrigation farms, it does not exceed 20 cm. In high flood areas, it goes as high as a meter.

Most diversion structures in traditional spate irrigation areas are spurs. They are constructed from earth, brushwood, sorghum roots, sand-filled bags, etc. Modern systems are built from masonry, concrete, and mesh wires, commonly called "gabions" or combinations of the above with metal control gates. In some cases, sheet metal canals are used to convey water in places of valley crossings. Further, using stone, brushwood, and trunks and making trenches to guide the water flow are traditional techniques to protect banks and train wadis. Modern spate irrigation systems differ from the traditional ones, mainly in their headworks. The traditional spate irrigation systems have temporary or seasonal headworks; their locations can be changed according to the command area; they can be quickly eroded and requires frequent maintenance. On the other hand, the headworks of modern spate irrigation systems are fixed in location, at its maximum water intake ability, and in intake level. Even if the contemporary headwork reduces the beneficiaries' repetitive and tedious headwork construction, it does not allow changing the location, status and achieving maximum flood intake.

The crops grown under spate irrigation depend on several factors such as food culture, market value, preference of farmers, and size of the farmland. Although sorghum is the main crop cultivated in most spate irrigation areas, some communities prefer maize over sorghum. Wheat and other cereals are also grown in some areas. The main income-generating crops cultivated in many spate irrigation areas are vegetables. In the eastern parts of the country, khat, coffee, and Sesame are the main income-generating crops grown under spate irrigation. Spate irrigation significantly affects crop productivity in arid and semi-arid areas. For example, wheat grain yield in one of the spate irrigation farms in central Ethiopia has increased from 0.3 to 3.2 tons/ha (Alemayehu, 2008). Another farmer in eastern Ethiopia could increase farm productivity from 0.8 to 2.0 tons/ha of grain sorghum. Similarly, sorghum production in one of the spate farms in northern Ethiopia recorded a two-fold increment, while an adjacent farm incurred total loss because of the absence of irrigation. Another farmer in the same area increased his chili pepper production from 1.0 to 5.0 tons/ha (Alemayehu, 2008).

In traditional spate irrigation areas, the floodwater only complements the actual rainfall directly received on the farm plots, which primarily influences different aspects of the microclimate to favor crop growth. Therefore, in most of the arid areas of Ethiopia, the contribution of floodwater in meeting the actual crop water requirements is very minimal. Thus, despite the traditional spate irrigation systems that provide lifesaving irrigation water, the production system remains primarily rainfed, making farmers vulnerable to intermittent failure/shortage of seasonal rainfall. The rapid deterioration of physical structures is another problem of the traditional spate system. The designs made of bush or soil are washed away by floods, which results in erosion of riverbanks and loss of farmlands. Frequent silting up of diversion canals is also one of the significant problems facing traditional spate systems in Ethiopia. The biggest operational problem of spate irrigation is the lack of equity among users. For instance, in some areas, individual users are given a date to use their share of floodwater. If there is no rainfall in the upstream catchment on that specific date, the person's turn will be canceled. Under such arrangements, with an unreliable rainfall pattern, individual farmers might miss an entire seasonal flood. Although no salinity problems are stated in spate irrigated areas, 30-50% yield reductions on sorghum and maize have been reported by large Wadi Laba floods in Eritrea (Mehari, 2007).

2.2 Modern irrigation schemes in Ethiopia

The development of modern irrigation schemes is a recent trend in Ethiopia. The Imperial Government in the 1950s took the first initiative in water resources development. Under this initiative, large-scale water development projects both for irrigation and power generation purposes were constructed. These developments were concentrated in the Awash Valley as part of the agro-industrial enterprise's development initiative. Later, such schemes gradually expanded to the Rift Valley and the Wabi Shebele basins. The focus of water resource development during the imperial period was on large-scale and high-technology water projects.

The construction of the first modern irrigation scheme started in the early 1950s following a bilateral agreement between the Imperial Government of Ethiopia and the Dutch company known as HVA-Ethiopia for the plantation of sugarcane (Bekele et al., 2012). In the 1960s and 1970s, large-scale sugarcane, cotton, fruit, and vegetable irrigation farms were established in the Awash River basin and Rift Valley areas. Surface irrigation methods (i.e., furrow and basin) were practiced for producing sugarcane, cotton, and horticultural crops on a commercial basis (Awulachew et al., 2007). This was followed by the establishment of agro-industrial centers such as sugar and garment factories. The Koka dam in the upper Awash valley was also constructed around the same time to serve as a reservoir for flood control and hydropower generation. During the Imperial regime, the main objective of irrigation development was to supply raw material to the growing agro-based industries in the country to meet domestic demand and increase export earnings.

Following the overthrow of the Imperial Government in 1974, all large-scale irrigation schemes were nationalized and handed over to the newly established Ministry of State Farms. Most landlord-based small-scale irrigation schemes were also handed over to producer co-operatives (Berhanu et al., 2014). The military regime was also keen to promote large-scale and complex water projects as part of its broader modernization and socialization plan to revive the country's agricultural economy. The nationalized agro-industrial and agricultural enterprises managed high technology water development schemes. However, little attention was given to small-scale and traditional irrigation schemes constructed and operated by smallholder farmers.

After the devastating famine of 1984/85, the military government started showing interest in small-scale water development schemes (MOA, 2011). Irrigation Development Department (IDD) under the Ministry of Agriculture was tasked to develop small-scale irrigation projects for the benefit of smallholder farmers (Berhanu et al., 2014). However, IDD's performance was slow, and only 35 small-scale irrigation schemes were constructed between 1984-91, of which about one-third were improved traditional irrigation schemes. Moreover, small-scale irrigation development was considered 'infrastructure development' grouped with rural roads and similar construction teams and staffed mainly with engineering personnel.

With the establishment of the new government in 1991, small-scale irrigation schemes and improved farmer-managed traditional systems came at the forefront of the water development policy. In 1994, IDD was dissolved while the government's interest in small-scale irrigation remained very high, as manifested by creating the Regional Commissions for Sustainable Agriculture and Environmental Rehabilitation (Co-SAERs). The Co-SAERs embraced the promotion of small-scale irrigation as a primary mandate. They emphasized developing and enhancing small-scale irrigated agriculture for food security at the household level (MoWR, 2002).

The degree of end users' commitment to resources and control over the system's operation is significant for irrigation schemes' successful operation and maintenance. For this purpose, irrigation schemes are categorized as public or private. Public irrigation schemes are those in which the government has the dominant financial interest or management responsibility/control. They may range from hundreds of thousands of hectares to a minimal of 10 ha or less. Public irrigation schemes tend to be supply-driven and may include political and social objectives;

therefore, farmers receive a subsidized service effectively. Private irrigation schemes are developed, controlled, maintained, and managed by farming communities independently of the government. These include small paddy plots in Southeast Asia; shallow groundwater wells in the Indo-Gangetic Plain; tank irrigation systems in Sri Lanka, India, and Nepal; qanat systems in Iran, Afghanistan, and Pakistan; the swamp and flood recession areas with partial water control in Sub-Saharan Africa (SSA); and spate irrigation systems in Southern Arabia. Private irrigation schemes are demand-driven, and farmers contribute to the capital costs and accept full responsibility for operation and maintenance. Another category is related to communal smallholder irrigation schemes, which are developed by self–help or through projects with external inputs by governments and non-governmental actors with the participation of farmers.

Farmers develop traditional irrigation schemes with irrigated areas varying from < 50 to 100 ha. Water user committees, locally known as 'water fathers', administer water distribution and coordinate maintenance activities of these schemes. These schemes are typical in peri-urban areas such as Addis Ababa and Bahir Dar. These schemes are used to produce vegetables for domestic consumption and the local markets. Major drawbacks of traditional irrigation schemes are related to unstable headworks and faulty systems of irrigation stemming from a lack of technology and knowledge of users.

Improved communal small-scale irrigation schemes are generally based on direct river diversions and may also involve micro-dams for storage to irrigate 20 to 200 ha. For example, the Oromia Irrigation Development Authority evaluation study disclosed that rivers are the primary water resources for improved small-scale irrigation schemes in the region. Out of the total 96 projects at the time, 72 obtain water from rivers through diversion weirs. The area covered by improved small-scale irrigation schemes in the Oromia region is 48,000 ha involving about 74,000 farmers (Ligdi et al., 2007). Although water users' associations (WUAs) have been established in some schemes, traditional water management dominates in most of these schemes. The operation and maintenance of these schemes are the responsibility of WUAs supported by regional irrigation and management authorities.

The private/commercial irrigation schemes (i.e., modern private irrigation schemes) were established in the 1960s and were owned by private farms until the military government nationalized them in the 1970s. Through privatization, some projects were transferred to private owners by adopting a market-based economy policy in the early 1980s and 1990s. Private investment in irrigation has recently re-emerged because of the policy change. Public irrigation schemes ranged from 200 to 3,000 ha. About 97,700 ha are estimated to fall under this category. These schemes are found along the Awash River course, constructed in the 1960s and 1970s as either private firms or joint ventures. Furrow and basin methods are primarily used for irrigation except in Fincha sugar estate in western Ethiopia, where sprinklers are used. The average irrigation efficiency of public schemes in the Awash basin is less than 40% because of inadequate land leveling and water control, lack of knowledge on crop-water demand, and lack of appropriate water measuring devices (Ayenew, 2007; Ligdi et al., 2007). Irrigation schemes in Ethiopia are divided into three main categories (Awulachew, 2010).

- *Small-scale irrigation (SSI):* These are community-based schemes covering < 200 ha. These include household-based rainwater harvesting, dug wells, shallow wells, spate, household-based river diversions, and other traditional methods. These schemes vary from micro-irrigation and household rainwater harvesting structures, pumping, small or large dams, etc.

- *Medium-scale irrigation (MSI):* These are community-based or public schemes covering 200 to 3,000 ha. Examples of MSIs include the Sille, Hare, and Ziway irrigation schemes, and;

- *Large-scale irrigation (LSI):* These are mainly commercial or public schemes covering more than 3,000 ha. For example, Wonji-Shoa, Methara, Nura Era, and Fincha irrigation schemes

Region-wise, 39% of the irrigated area is in the Oromia region in central Ethiopia, followed by 24% in the Amhara region in the north, 15% in the Afar region in the northeast, and 12% in the South region. In comparison, the remaining 10% is in other areas. Nearly 100% of the irrigated land is supplied with surface water, while the groundwater irrigation has just started in the East Amhara region. Sprinkler irrigation is practiced on about 2% of the irrigated area, mainly for sugarcane production by government enterprises. Groundwater exploitation by treadle pumps has recently been started in the Tigray and Amhara regions. Spate irrigation and flood recession cropping systems are practiced in the lowland areas of the country, particularly in Dire Dawa, East Oromia, Somali, East Amhara, and south Tigray parts of the country. The distribution of irrigation schemes in Ethiopia is given in Figure 2.

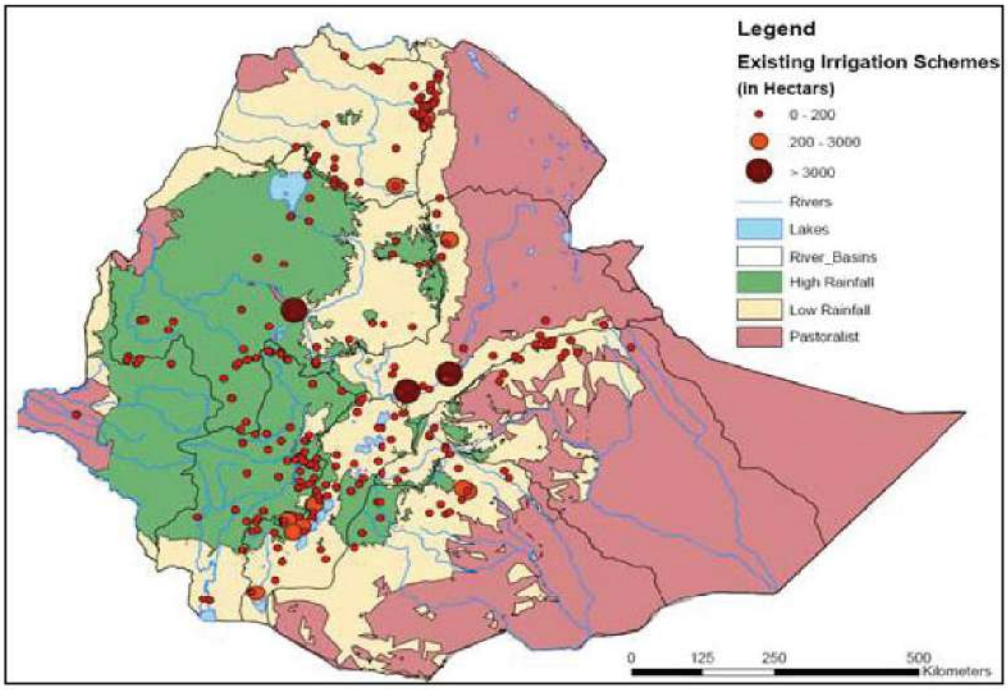


Figure 2. Distribution of irrigation schemes in Ethiopia

Several large-scale public irrigation projects are currently under construction in the country, of which 75% are located in Awash, Blue Nile, and Wabi Shebelle river basins. These include:

- *Kesem and Tendaho Irrigation Projects* within the Awash Basin, covering 90,000 ha.
- *Ethiopian Nile river basin irrigation and drainage projects* - are found in the Abay and Tekeze Bazins, which form the Blue Nile basin in Ethiopia.
    - Arjo-Dedesa irrigation project - is in the Abbay basin covering an area of 14,300 ha.
    - Humera irrigation Project - is in the Tekeze basin covering an area of 43000 ha.
    - Gumara irrigation project - is within the Nile Basin, covering an area of 14000 ha.
- *Lake Tana Sub-Basin Irrigation projects* - These include Jemma, Megech, Rib, and Gilgel Abay projects, covering an area of 62,457 ha.
- *Koga irrigation project* - is in the Abbay basin with a total irrigable area of 7000 ha.
- *Lake Abaya Sub-basin irrigation projects* - are located in the Rift-valley Lakes basin. These include Gelana, Gidabo, and Billate irrigation projects with a combined area of 31,920 ha.
- *Ziway irrigation project* – is in the rift valley lakes basin covering 15,500 ha of irrigable land.
- *Wabi-Shebele basin irrigation projects* - are in the Wabi-Shebele basin with a total area of 52,920 ha. The projects include Golgolcha, Error, Illiyon, and Buldaho irrigation projects.
- *Raya Valley Pressurized Irrigation project* – is located in Danakil dry basin. Its source of water is groundwater. The project has a total irrigable land area of 18 ha
- *Kobo-Girona Pressurized Irrigation project* - is located partly in the Danakil dry basin and partly in the Awash River basin. Its source of water is groundwater, covering an area of 17,000 ha.
- *Wolkyte irrigation project* - is in the Tekeze basin with a total irrigable area of 40,000 ha.

2.3 Irrigation development in Ethiopia

The Ethiopian economy is mainly dependent on rainfed agriculture, which is less developed, practiced dominantly by smallholder farmers. It accounts for 40% of the GDP, 80% of exports, and an estimated 75% of the workforce (USAID, 2021). The arable land in Ethiopia is estimated between 50-70 million ha (Mha), of which about 15 Mha is cultivated. The country has an annual surface runoff of 124 billion cubic meters (Bm3), with more than 90% owing in Transboundary Rivers. The groundwater potential of the country is estimated between 30-40 Bm3. Land and water are the two principal resources for irrigation potential and development. In Ethiopia, water is scarcer than land and is a limiting resource for irrigation development. The area under irrigation is only 15-20% of the potential, revealing the underutilization of available land and water resources for irrigation development.

Irrigation development has been at the center of all national development plans over the last two decades. Accordingly, ambitious plans for irrigation development have been ambitious in the Growth and Transformation Plans GTP I (2011-2015) and GTP II (2016-2020). However, the achievement in the sector remained very low due to several limitations such as planning and execution capacity, financial, technical, etc. Different actors undertake irrigation development, including the Ministry of Water Irrigation and Energy (MOWIE), the Ministry of Agriculture (MoA), regional governments, and NGOs. The actual irrigated area is not precisely known. However, MoWIE has estimated that the total irrigated area is about 1.2 Mha.

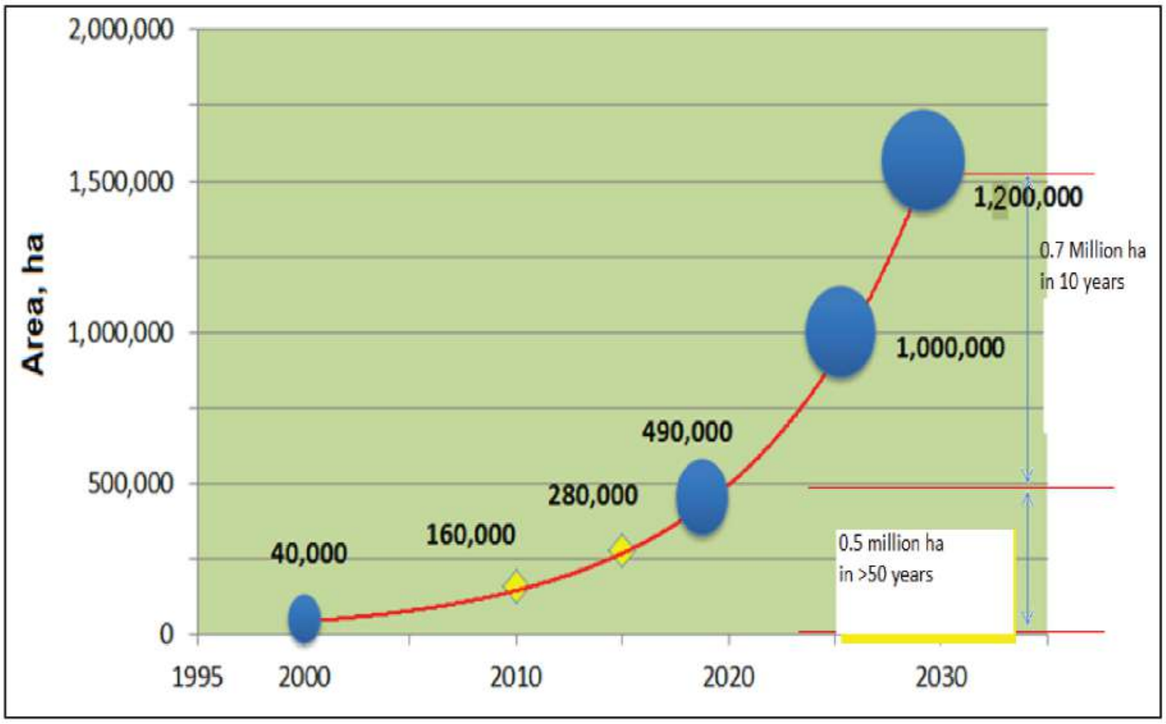


Figure 3. Trends in the expansion of medium and large scale irrigation in Ethiopia

The irrigated area in Ethiopia is not precisely known and documented. A recent inventory of existing irrigation schemes indicates that the area under large and medium scale irrigation schemes is about 35% and 58% of the planned potentials, respectively. The total planned potential area of existing large and medium scale irrigation schemes (operational and semi-operational) is about 660,250 ha (133,518 ha medium scale and 526,732 ha large scale). In comparison, the irrigated areas are 265,014 ha (77,804 ha medium and 187,210 ha large scale). Overall, for medium and large-scale irrigation schemes, the area under irrigation accounts for about 40% of the planned areas (Table 1).

Table 1. Planned and actual irrigated areas in different river basins in Ethiopia.

River Basin	Area planned and irrigated								
	Medium size irrigation			Large size irrigation			Total		
	Planned	Irrigated	%	Planned	Irrigated	%	Planned	Irrigated	%
Abbay	6,010	1,817	30	137,436	38,500	28	143,446	40,317	28
Awash	16,542	4,565	28	166,393	76,296	46	182,935	80,861	44
Baro-Akobo	2,287	1,100	48	10,000	1,500	15	12,287	2,600	21
Genale Dawa	2,857	1,297	45	0	0	0	2,857	1,297	45
Omo Gibe	31,580	12,352	39	97,983	24,494	25	129,563	36,846	28
Rift Valley Lakes	43,013	32,081	75	10,920	9,420	86	53,933	41,501	77
Tekeze	5,118	970	19	50,000	30,000	60	55,118	30,970	56
Wabi-shebelle	26,113	23,622	90	54,000	7,000	13	80,113	30,622	38
Total	**133,520**	**77,804**	**58**	**526,732**	**187,210**	**36**	**660,252**	**265,014**	**40**

Small-scale irrigation systems in all forms, including traditional, semi-modern, modern, household, are also widely practiced in Ethiopia. These schemes are commonly practiced in a disintegrated and localized manner, either communally or by individuals. Therefore, the area under small-scale irrigation schemes is not precisely known. In several cases, the beneficiaries make contributions mainly by providing labor to enhance the sense of ownership. Small-scale irrigation schemes are significant to Ethiopia owing to their suitability for smallholder farmers, low capital investments, and simplicity to operate. However, the attention given to small-scale irrigation schemes is not sufficient. Although the actual irrigated area of small-scale irrigation is unknown, estimates of gross irrigated areas of 1.2 million have been reported (MoWIE, 2020). About 265,014 ha is under large-scale and medium-scale irrigation; thus, the remaining 934,986 ha (78%) would account for small-scale irrigation schemes.

Smallholder farmers often plan crop choice, water application method, and market linkages without support from extension services and generally struggle to obtain optimal benefits. Hence, because of a lack of experience, households tend to plant non-commercial and the same types of crops and vegetables. This gradually reduces their production and farm incomes.

2.4 Irrigation typology in Ethiopia

Irrigation schemes are usually categorized based on system size, the nature of the water source, degree of water control, and whether they are operated publicly or privately. Organizing irrigation schemes by size has difficulties on a global scale. What might be considered large-scale schemes in some countries could be small-scale or medium-scale in other countries. For instance, in India and Pakistan, an irrigation scheme of 10,000 ha is classified as a 'small-scale' scheme, while in Ghana, the largest irrigation scheme is 3000 ha. During the 1960s and 70s, irrigation schemes were classified based on the command area: small-scale irrigation (< 200 ha), medium-scale irrigation (200-3000 ha), and large-scale irrigation (>3000 ha). Table 2 shows the factors for irrigation typology based on technology and scheme management (Agedi et al., 2016).

Large-scale farms are owned by private companies or the government, whereas small-scale farms are owned by individuals or communities (Ligdi et al., 2007). Other criteria used for classifying irrigation schemes are materials used, ownership, and management. Based on ownership and control, irrigation schemes are divided into four categories: (1) small-scale traditional schemes owned and managed by farmers; (2) modernized small-scale irrigation schemes with more permanent diversion structures, mainly community-managed; (3) large-scale public schemes are constructed, operated, and managed by the government; and (4) privately owned irrigation schemes that require a highly intensive operation.

The irrigation typology in Ethiopia is based on the size of irrigable areas and modalities for developing and managing the schemes. Irrigation typologies are described in Tables 3 and 4.

Table 2. . Factors for irrigation typology

No.	Criteria	Description
1	Source of water	Reliability of the water source Impacts on ecosystem Upstream/downstream relation Water quality
2	Mode of abstraction	Presence of fixed structure Mechanism for abstraction Reliability/durability Independence Ease of operation
3	Water conveyance system	Types of conveyance systems Independent for operation Level of risk of water loss Canal capacity Canal crossing structures
4	Flow control structures on conveyance and distribution	Presence of control structures at offtakes Appropriateness/types Simplicity of operation Measurement facility Ease of repair and maintenance
5	On-farm application (water management practices)	Methods of regulation of water application practices Appropriateness of water application method On-farm erosion Crop choices
6	Drainage system	Presence of flood control structures Presence of adequate drainage system Functionality
7	Irrigation water users organizations	Presence of IWUA Written bylaws Enforcement of bylaws

Table 3. Typology of irrigation based on the size of the irrigated area.

No.	Typology	Irrigated area (ha)	Remarks
1	Micro/household irrigation	< 5 ha	Mainly practiced at household levels using water from farm ponds, shallow wells, springs, small streams, etc.
2	Small-scale irrigation	< 200 ha	These are communal irrigation schemes with traditional, improved, or modern infrastructure. The users can develop these projects with little external support from the government or other actors.
3	Medium-scale irrigation	200 -3,000 ha	Mostly communal, developed by the government
4	Large-scale irrigation	> 3,000 ha	These are schemes irrigating larger areas and often have modern irrigation infrastructure. The government or private investors make them. The schemes can be community-based, private, or public.

Table 4. Typologies of irrigation based on irrigation and management modalities.

No	Typology	Irrigation technology description	Management
1	Traditional small scale irrigation schemes	Temporary headwork, such as simple diversion, with sand gags, stones, soil, logs, etc. Poorly constructed earthen canals with no permanent flow control structures.	Community management
2	Semi-modern small scale irrigation schemes	They consist of permanent headworks, river diversion, and pumping stations but lack adequate water conveyance and control infrastructure. Poorly designed surface irrigation is practiced	Community management (Water Users Associations)
3	Modern private commercial schemes	It consists of pumping stations of rivers or groundwater headworks and irrigation infrastructure, including water conveyance, distribution, and application. Drip irrigation is widely practiced, particularly for horticultural crops.	Private management
4	Modern large-scale community schemes	Have modern headwork such as dams and diversion and conveyance and flow control systems. The government constructs these for smallholder farmers.	Water Users Associations
5	Large scale public irrigation schemes	It consists of modern headworks such as dams, diversion weirs, and pumping stations. They also have modern water conveyance and control infrastructure.	Central management

Typical flow control in a traditional irrigation scheme

Typical features of the semi-modern irrigation scheme

Headwork for a modern large scale community irrigation scheme

Conveyance and flow control systems of the modern public irrigation scheme

2.5 Irrigation methods and practices in Ethiopia

The current irrigation systems and technologies in Ethiopia are by large less developed. The on-farm and off-farm water management practices are often poor and ineffective, resulting in substantial water losses. In Ethiopia, surface irrigation is primarily characterized by poorly designed field systems, poor land grading, inappropriate furrow sizes, and flows, and widely practiced flood irrigation. These are the significant factors for non-sustainable irrigation management and water-logging and salinity effects. Modern irrigation systems such as sprinklers and drip are limited to a few large irrigation schemes and growing horticultural crops and flower farms. These irrigation systems account for about 2% of the total irrigated area in Ethiopia. The remaining 98% area is irrigated by surface (flooding) irrigation method.

03

WATER RESOURCES MANAGEMENT IN ETHIOPIA

3.1 Surface water resources

Ethiopia has substantial water resources comprising 12 river basins, 11 fresh lakes, nine saline lakes, four crater lakes, and more than 12 significant swamps and wetlands (Kidane et al., 2006). The total mean annual runoff volume from the 12 river basins is 122 billion m3 (Bm3), with the Abbay basin (in central and northwest Ethiopia) accounting for 45% of this amount (Figure 4). Much of this run-off could be used for irrigation or other purposes. Out of 12 river basins, eight are wet river basins, while the remaining four are dry basins with insignificant surface water resources contributions (Table 5). The surface water systems of the wet river basins flow into two main directions based on their position from the Great Rift Valley that dissects the country into two major sections: West and East (Berhanu et al., 2014). The rivers that originate from the western side of central highlands and western plateaus of the country are flowing to the west and joining the Nile system. These include the Abbay, Baro-Akobo, Mereb, and Tekeze basins. The second section contains the basins originating from the Eastern Highlands and flowing toward the east, including Wabi Shebelle and Genale Dawa Basins. River systems flow along the Great Rift Valley, including Awash and the Rift Valley Lakes basin rivers. The Omo Ghibe river is the only primary river system flowing from the North to the South (Figure 5).

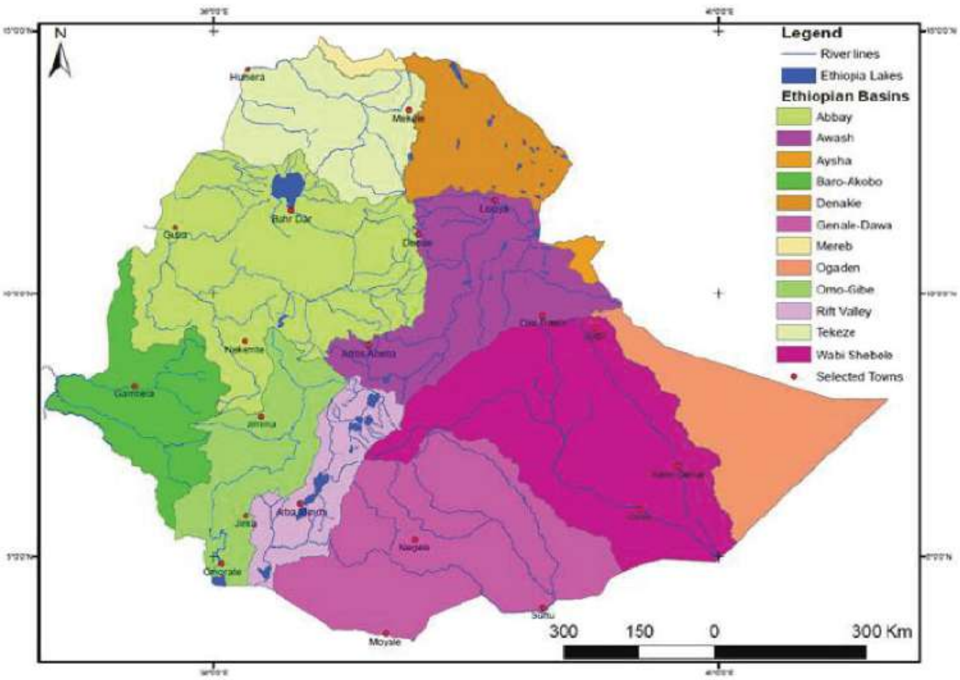


Figure 3. Major river basins of Ethiopia

The surface water resources have the potential to irrigate 3.7 million hectares (Mha). However, due to limited water infrastructure and storage capacity, this potential has not been fully utilized for the socio-economic development of its people. There is substantial temporal and spatial variability in the surface water resources. For almost all the major rivers, about 80% or more of the flows occur in just four months (June-September), while flows are minimal over the rest of the months. Due to lack of control and storage, devastating floods are significant water management challenges during the peak flow period, particularly in the lower reaches of Awash, Omo, Baro Akobo, and Abbay basins. For example, Ethiopia's current per capita water storage capacity is 160 m3 (Awulachew, 2010).

The spatial variability of the surface water resource is even worse. The vast Eastern, North-eastern and southern, southern parts of the country are arid and semi-arid with little rainfall, covering about 40% of the country's landmass. In these regions, there is a severe water scarcity for domestic, agricultural, and livestock watering. About 60% of the country's water resources occur over areas where only 40% of the population lives (Awulachew, 2008).

). In 40% of the total land mass (semi-arid and arid), agriculture is mainly not possible without irrigation. If it exists in limited semi-arid areas, crop failures commonly occur due to the lack and unreliability of the natural rainfall. In addition to the deteriorating water quality, reducing the water volumes (river flows) has been witnessed in several basins and sub-basins over the last few decades. This, in combination with a fast-growing population, has been a cause for ever reducing per capita water availability in Ethiopia. Ethiopia's per capita water availability is about 1,100 m3 per year, close to the threshold value of 1000 m3 per year for water scarcity. On top of this, more than 91% of the surface water resources flow in transboundary water courses, so the amount of 124 Bm3 is not an accurate available volume for utilization. Therefore, Ethiopia is practically not a water-rich country but a nation approaching a water stress situation.

Table 5. Characteristics of major river basins of Ethiopia.

River basin category	River basins	Area (Km^2)	% of total area	Annual Runoff	% of total runoff
Wet Basins	Abbay	199, 812	17.6	54.5	44.1
	Awash	112,696	9.9	4.6	3.7
	Baro-Akobo	75,912	6.7	23.6	13.4
	Genale Dawa	171,042	15.1	6.6	5.3
	Omo Gibe	79,000	7.0	16.6	19.1
	Rift Valley Lakes	52,739	4.6	5.3	4.3
	Tekeze	82,350	7.3	8.2	6.6
	Wabi-Shebelle	202, 697	17.9	3.16	2.6
	Sub –Total	976248	86.0	122.56	99.1
Dry Basins	Aysha	2200	0.2	0	0.0
	Denakil	74,000	6.5	0.86	0.7
	Mereb	5,700	0.5	0.65	0.2
	Ogaden	77,100	6.8	0	0.0
	Sub –Total	159000	14.0	1.51	0.9
Total		**1,135,248**	**100.0**	**124.07**	**100.0**

(Source: Awulachew et al., 2007)

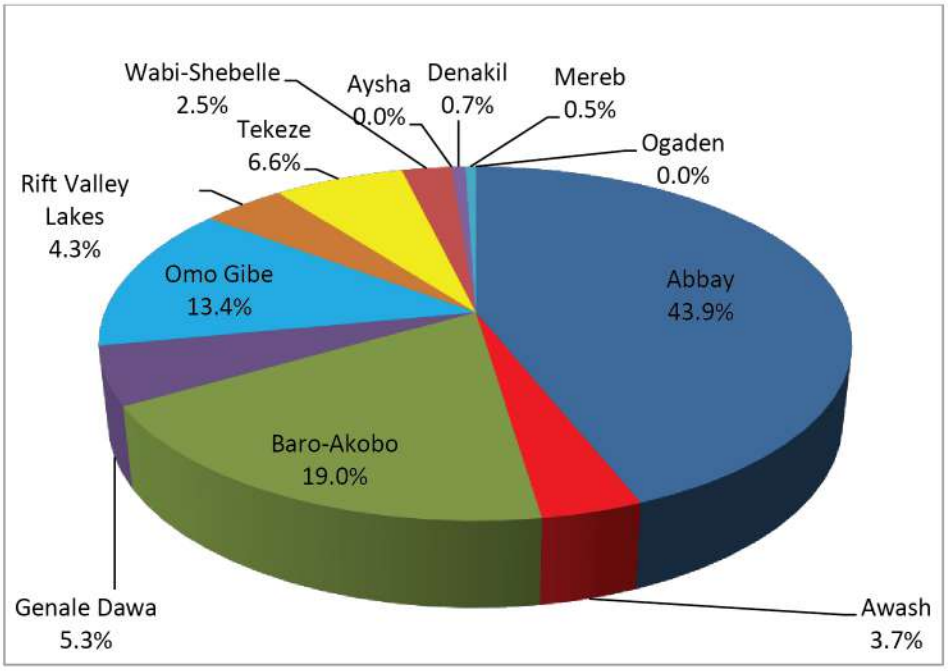


Figure 5. Surface water contributions of major river basins in Ethiopia.

3.2 Groundwater resources

Ethiopia's groundwater potential has not been widely studied. Initial estimates suggest that groundwater potential varies from 2.6 to 13.5 Bm3. The groundwater resources potential of Ethiopia was also recently estimated to be about 40 BCM (Mengistu et al. 2019). Despite this vast potential, groundwater exploitation for agriculture has been prolonged for multiple reasons, including hydro-geological complexity and high drilling costs. It is estimated that over 70% of Ethiopia's domestic water supply comes from groundwater. Regardless of its importance as a source of domestic water supplies in many parts of the country, groundwater is not uniform because it depends on various environmental, physical, and geological factors (Berhanu et al., 2014). Total irrigation potential from groundwater resources is estimated at 1.1 Mha (Awulachew, 2010). Figure 6 shows the preliminary groundwater potential map based on elevation, aquifer productivity, and moisture availability.

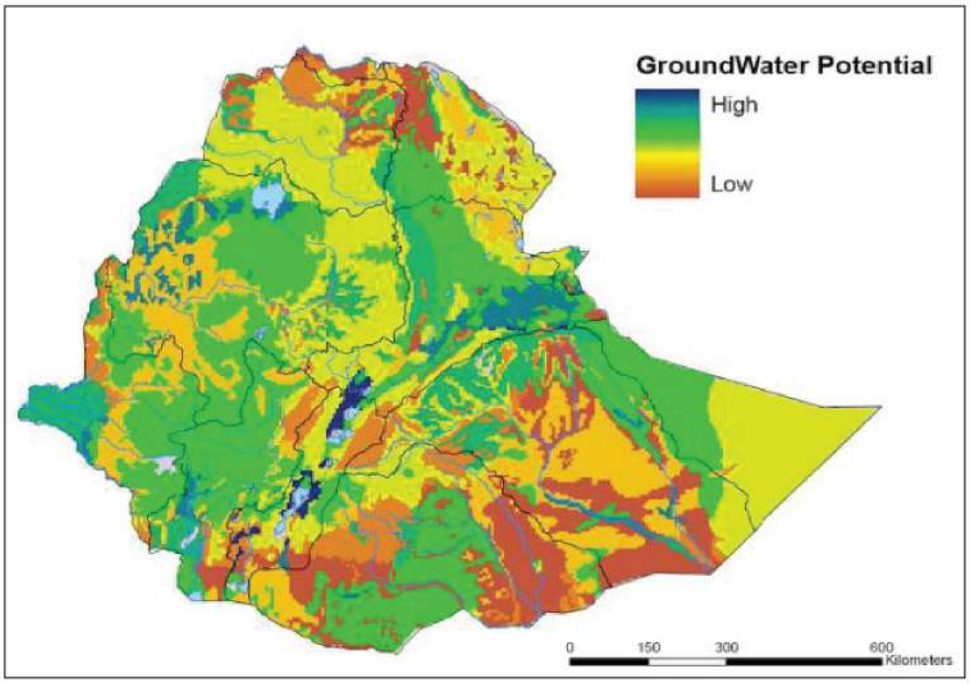


Figure 6. Preliminary map of groundwater potential in Ethiopia

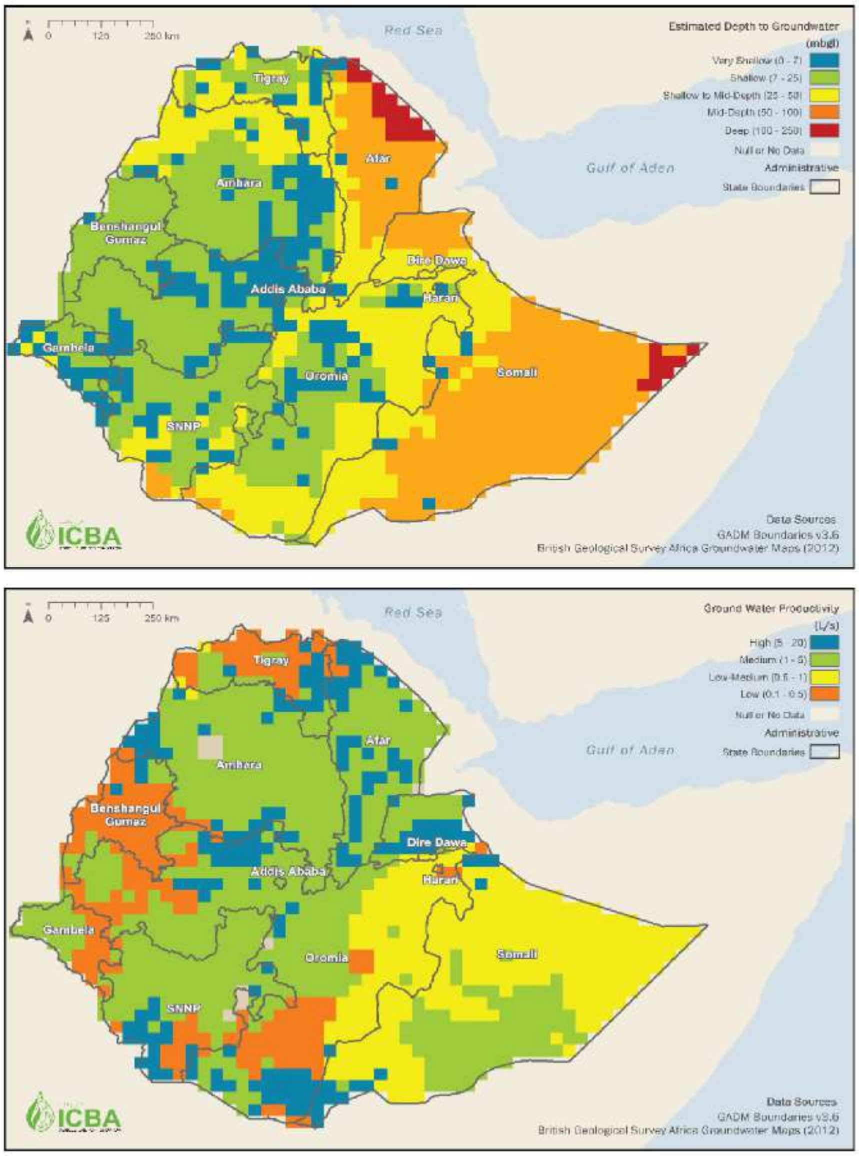
Estimation of groundwater recharges at basin levels is a good indicator of groundwater resources. Of course, several factors determine renewable groundwater availability, and mere recharge shall not imply continuous availability for exploitation. Still, with recharges known, renewable groundwater reserves can be estimated on realistic ranges. The average annual groundwater recharge in Ethiopia's eight wet river basins is shown in Table 6 (Ayenew et al., 2008).

Table 6. Average groundwater recharge in eight wet river basins of Ethiopia.

River Basin	Area (km^2)	Average recharge (mm)
Abbay	199, 812	100
Awash	112,696	30
Baro-Akobo	75,912	120
Genale Dawa	171,042	30
Omo Gibe	79,000	100
Rift Valley	52,739	50
Tekeze	82,350	50
Wabi- Shebelle	202, 697	30

The groundwater table depth in most parts of Ethiopia is relatively shallow, ranging from 0 to 25 meters. However, it can be up to 100m in other areas, resulting in higher drilling costs and low productivity. Groundwater productivity is deficient in many parts of Ethiopia (0-5 l/sec), making it economically unfeasible to exploit. The low groundwater productivity is attributed to insufficient groundwater storage in most parts of Ethiopia (Figure 7). Due to the aforementioned factors, groundwater irrigation development in Ethiopia has been slow compared to many Asian regions where conditions are more suitable for groundwater extraction.

Farmers often hold back from investing in groundwater irrigation because of the high drilling and energy costs for tubewells and lack of information about groundwater availability (Kadigi et al., 2012). The drilling cost in SSA is US$ 100 per meter, which is ten times higher than the cost of drilling in most Asian countries (Barker and Molle, 2004). The exploration and utilization of groundwater have also been low in Africa due to low-yielding aquifers (FAO, 2015) because they do not support high-capacity tubewells. Therefore, extracted groundwater quantities are low to practice surface irrigation methods such as flooding or basin. Under these circumstances, drip and sprinkler irrigation systems are better suited to increase agricultural productivity in Sub-Saharan Africa (Svendsen, 2009).



Data Sources
GADM Boundaries v3.6
British Geological Survey Africa Groundwater Maps (2012)

Figure 7. Groundwater table depth and productivity in Ethiopia.

3.3 Rainwater

Ethiopia has considerable rainfall, but its distribution is highly variable, and most of it occurs in a limited period of the year. Ethiopia is divided into 32 major agroecological zones (AEZs) based on temperature and moisture regimes. These AEZs are further divided into three rainfall zones. These include the high rainfall zone, low rainfall zone, and the pastoralist zone (Awulachew, 2011) (Figure 8).

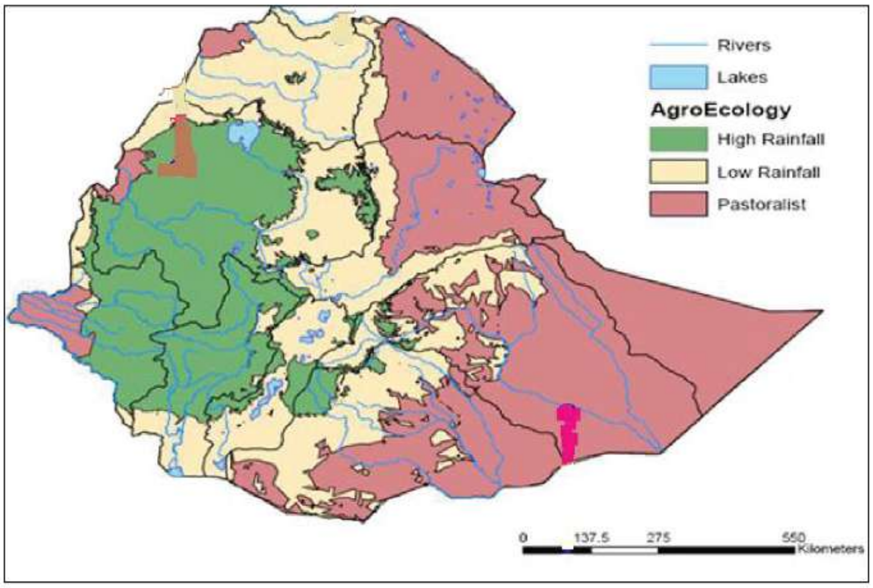


Figure 8. Three major rainfall zones in Ethiopia.

The average annual rainfall in the high rainfall zone exceeds 800mm. This zone covers 24% of the country, producing 51% of the permanent crops, and 43% of the total population lives in this zone. The land is not particularly vulnerable, nor is it very productive. The farming systems in these zones are typically mixed crop-livestock, though crops dominate. Here, irrigation would be supplementary to produce a second crop and increase productivity.

The low rainfall zone covers 32% of the land, 47% of the population, and 39% permanent crop output. The average annual in these zones is generally less than 600mm and is highly variable. The lands in this zone are moderately degraded. Dominated by crops, the farming systems are still mixed crop-livestock. These areas are often vulnerable and constrained by low productivity and overpopulation. Here, irrigation could secure food production, improve livelihoods, and increase food resilience.

The third zone is the pastoralist, covering 44% of the country's land, 10% of the population, and producing 10% permanent crops. In this zone, the average annual rainfall is lower than 600mm, except in the west part of the country. In most of this zone, pastoralist, livestock-based, and non-sedentary lifestyles prevail, and these areas are constrained by vulnerability and low livestock productivity. Irrigation would create livelihood options and increase food resilience in these communities.

The rainfall in Ethiopia varies spatially and inter-annually. The mean yearly precipitation ranges from 141mm in the arid area of the eastern and northeastern borders of the country to 2,275mm in the southwestern highlands (Berhanu et al., 2014). The annual rainfall classes in Ethiopia are shown in Figure 9. About 80% of the total rainfall occurs between June and September, with about 30% inter-annual variability. Therefore increasing storage capacity and improving water control and rainwater management techniques, especially rainwater harvesting (RWH), is critical to ensure that Ethiopia gets maximum use of its rainfall.

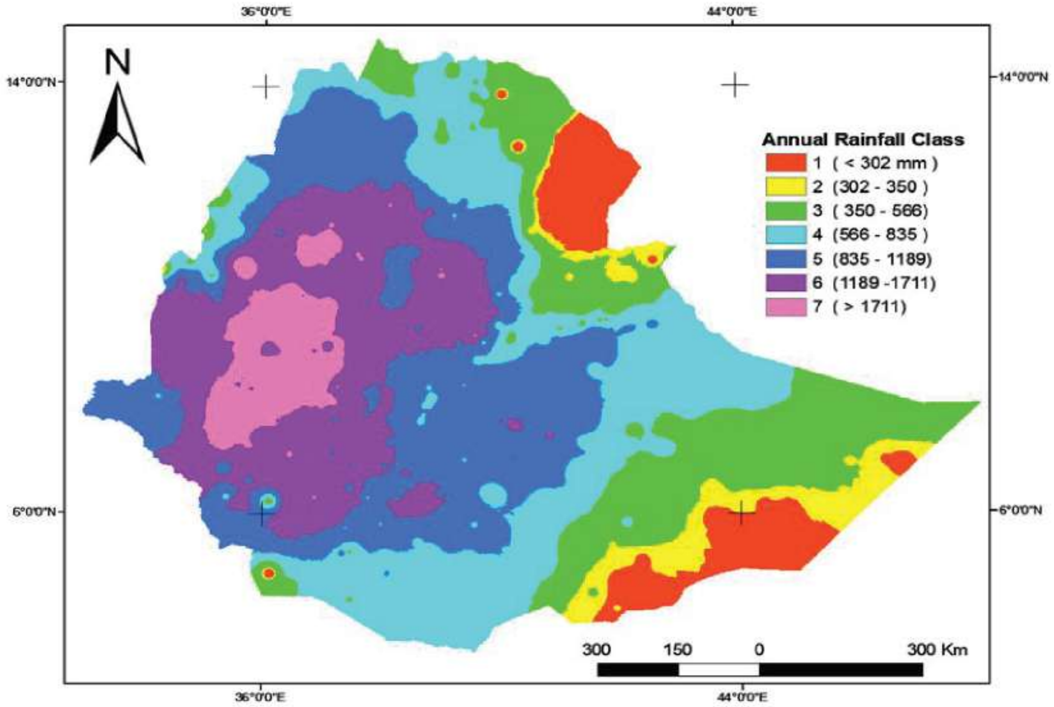


Figure 9. Annual rainfall classes in Ethiopia.

3.4 Spatio-temporal variability in the water resources

There is substantial Spatio-temporal variability of the surface water resources in Ethiopia. The surface water resources of the country follow rainfall patterns. The magnitude of the mean annual rainfall in the country's southeast, east, and northeast borders is less than 200mm. The central and western highlands of the country receive a mean yearly rainfall of more than 1,200mm. The eastern flowing river basins (Wabi-Shebele and Genale-Dawa) receive low to medium rain. In contrast, those that flow to the west (Abay, Baro-Akobo, Omo-Gibe, and Tekeze) receive a mean annual rainfall in the range of medium to high (Berhanu et al., 2014).

Spatially, 70% of the country's surface water resources are located in the Western and southwestern parts, covering only 40% of the country's landmass (Figure 10). The population in this part of the country is not more than 30 to 40% (Awulachew et al., 2007). The four river basins that contribute this 70% of the water resources are Abay (Blue Nile), Tekeze, Baro Akobo, and Omo Gibe. However, the water resources available in the eastern and central river basins are 10 to 20%, with over 50% population. There is severe water scarcity in the country's southern, eastern, and northeastern parts, whereas there is little or no resource limitation in the western and southwestern basins.

The temporal variability of the surface water resources of the country also follows the rainfall pattern. There is substantial temporal variability of flows in all the rivers. In general, about 70-80% of the river flow volumes occur in three or four months (June to September) for all the rivers, while only 20-30% of the flows occur in the remaining eight or nine months (Figure 11). The basins that receive two rainfall seasons have two peak flows. But the basins in the west primarily receive one rainfall season and peak flow months. Although the basins in the west receive a single season rainfall, they receive the most significant amount of rain, and thus the flows occur in just three or four months.

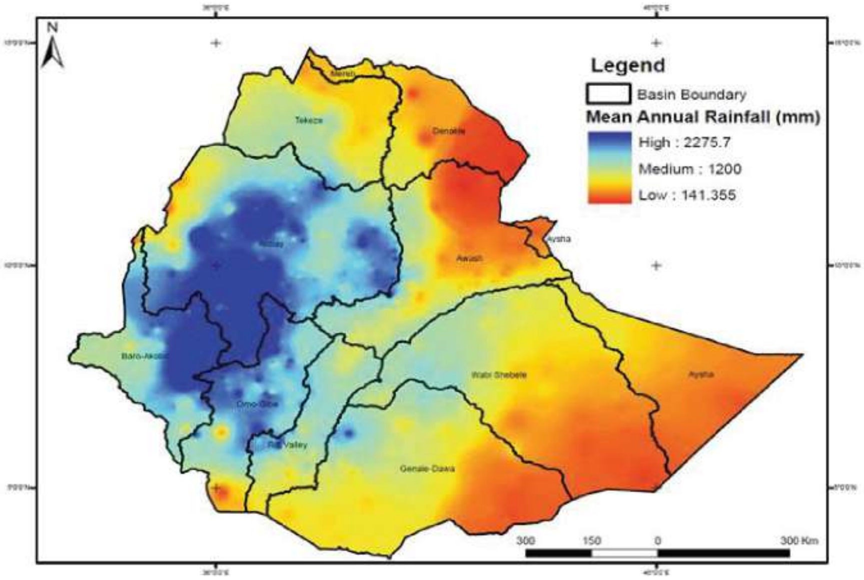


Figure 10. Spatial variability of mean annual rainfall in Ethiopia.

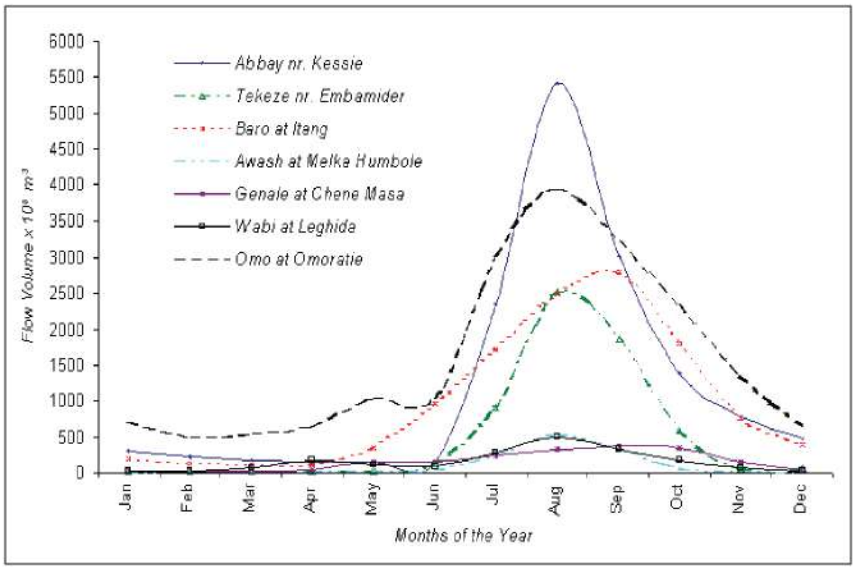


Figure 11. Temporal variability in the major river basins of Ethiopia

3.5 Irrigation potential in Ethiopia

According to the data from Master plans studies of river basins, the surface irrigation potential of Ethiopia is estimated as 3.7 million (Awulachew et al., 2007). However, this focuses on large-scale and medium-scale irrigation and does not address potential developments from small-scale irrigation, including minor river diversions, groundwater irrigation, and rainwater harvesting. Later, Awulachew & Ayana (2011) highlighted an additional one million ha potential from groundwater and 0.5 Mha from rainwater harvesting. The total irrigation potential, thus, was estimated to be about 5.3 Mha.

According to more recent studies (MoWIE, 2021), the suitable land in Ethiopia for irrigated agriculture (having land slopes less than 15%) is about 46 Mha for surface and pressurized irrigation practices. According to the Ministries of Agriculture and Energy estimates, the country's irrigation potential is 11 Mha (MoA and MOWIE, 2018). Therefore, a careful assessment of the country's irrigation potential could be 7.5 Mha to 11 Mha.

04

CHALLENGES OF IRRIGATION DEVELOPMENT IN ETHIOPIA

Despite concerted efforts, the expansion of irrigation in Ethiopia is constrained by several factors, including policy, institutions, technologies, capacity, infrastructure, and markets (Awulachew, 2010). Moreover, the sustainability of irrigated agriculture in arid and semi-arid regions of Ethiopia is also challenged by soil salinity, lack of adequate subsurface drainage, and poor on-farm irrigation practices (Wichelns and Qadir, 2015). As a result, many irrigated areas in Ethiopia perform lower than their potential (Hordofa et al., 2008). Most of the 791 irrigation schemes in Ethiopia are located in the arid and semi-arid lowlands, do not have functional drainage systems, and lack appropriate water management strategies (Awulachew et al., 2007). This situation has led to a gradual rise of the saline groundwater table that contributed to secondary salinization in large irrigation projects in the Rift Valley, Awash, Wabi-Shebele River Basins, and other places. Despite this situation, not much attention has been given to the drainage problems.

The majority of the operational irrigation schemes in the country are performing below their defined potential. Primary reasons for this poor performance include inappropriate irrigation scheduling, inadequate operation plans, lack of adequate institutional setups, inadequate physical water control facilities, canal sedimentation, lack of sufficient maintenance and appropriate asset management. Some of these challenges are critical to small-scale community-managed schemes, while others are fundamental to large-scale projects. The challenges of small-scale irrigation schemes are related to low levels of expertise, knowledge, and capacity to develop and manage irrigation systems. Initial investment costs for installing small-scale irrigation technologies (pumps and motors) and the operational costs (fuel and O&M costs) are also considered the major problems in adopting these innovative irrigation technologies by smallholder farmers. Most of the installed irrigation schemes are currently not operational due to poor maintenance. This situation has undermined the expected benefits of irrigation on the agriculture sector for the country's socio-economic development. Besides, this has also been a cause of wastage of scarce financial resources allocated to the sector.

4.1 Lack of adequate water storage facilities

For countries like Ethiopia with high seasonal rainfall variability, water storage facilities are critical. Storage infrastructures enable the regulation of the water resources available throughout the year. Water storage capacities are good indicators of the levels of water security of nations and vulnerability. Ethiopia has very low per capita water storage capacity, although there have been increases over the last two to three decades. Ethiopia's per capita water storage capacity has increased from 92 m3 in 1995 to 296 m3 in 2017 (Knoema, 2017) (Figure 12).

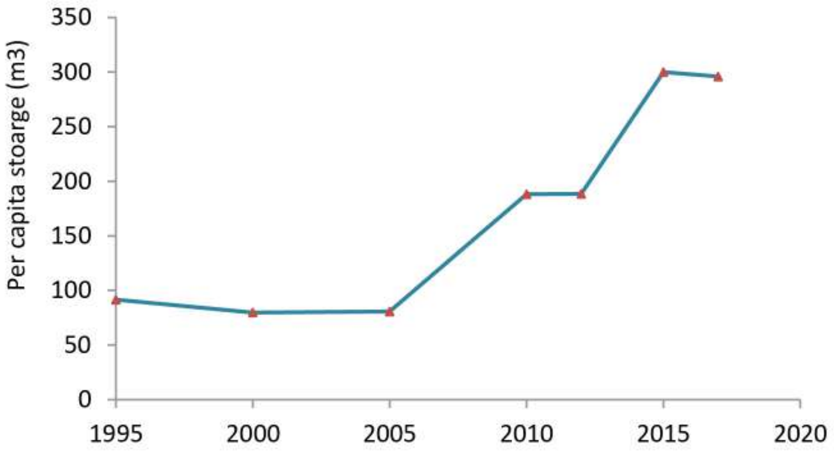


Figure 12. Increase in per capita storage in Ethiopia from 1995-2015.

4.2 Technical and design gaps

The performance of irrigation schemes in Ethiopia is 30% below design estimation (Awulachew et al., 2007). The main issue contributing to operational problems is the flaws in the design of irrigation schemes and the way they are managed. Flawed designs without considering geographical and hydrological factors have contributed heavily to the performance of irrigation schemes. Notably, in traditional systems, proper diversion, regulation, storage, and control structures are lacking. Drainage is usually neglected. This situation has led to water scarcity and conflicts arising due to inequitable water distribution to users/farmers. Poor distribution infrastructure design has also forced farmers to irrigate from plot to plot, contributing to water wastage and shortage in downstream command areas.

4.3 Lack of quality inputs and market for products

Smallholder farmers could not realize the benefits of irrigated agriculture because of limited access to quality seeds, scarcity of local wholesalers, absence of agro-processing and storage facilities. Poor market linkages force farmers to sell their crops directly from the field, leading to lower prices than market prices. Improper selection of crop varieties selection, crop rotations, inappropriate cropping patterns, low cropping intensities, non-availability of farm equipment, poor land leveling, inadequate soil fertility management, lack of information on irrigation scheduling and crop-water-requirements, inappropriate irrigation methods, and ineffective crop pest management practices are significant constraints around irrigation water and crop management.

4.4 Weak research and extension service

The primary extension connection with farmers in the Ethiopian extension system is the development agent (DA). DAs operate at the kebele (parish) level, the lowest administrative state in Ethiopia. A DA covers over 600 farmers, which is too big for proper delivery of the required services, especially where there is little/no means of transportation. The DAs have limited knowledge of on-farm water and crop management practices. Therefore, they cannot educate farmers on efficient irrigation techniques to avoid field losses and save crops from pest and insect attacks.

4.5 Poor input supply and credit facilities

In Ethiopia, farm inputs such as improved seeds, fertilizers, agrochemicals, improved farm implements, and technologies for water pumping and lifting devices are not available on time and at affordable prices. The organized input distribution system or estimation of input requirements is scarce. The main inputs for distribution are micro-irrigation equipment, seeds, seedlings, and fertilizers. The credit facilities are either absent or available only in a limited number of schemes. The input supply and credit systems are mainly designed for rainfed regions. The lack of access to nearby markets has reduced the farmers' income as they do not get the accurate price of their produce. The smallholder farmers do not have a market structure for their produce. Traders fix prices while farmers have little or no power to bargain. Storage of farm products and quality control systems are not available that have negatively affected farmers due to high post-harvest losses.

4.6 Institutional and policy constraints

Lack of clarity in mandates, roles, responsibilities, and poor collaboration and networking are the most significant institutional gaps responsible for poor handling of irrigation systems. Low institutional capacity at all levels is critical to enhancing the development of small-scale irrigation (SSI) concerning planning, design, implementation, operation, and maintenance, including irrigation advisory services. Similarly, poor linkages and limited capacities existed in agricultural research centers and water users' associations. The need to improve human resources is also highlighted. Limitations in the budget to expand SSI are also indicated as one of the main constraints.

4.7 Environmental problems

Expanding irrigated land in Ethiopia is possible due to its vast underutilized land and water resources potential. However, waterlogging and salinization are the two major environmental issues challenging the sustainability of existing irrigation schemes. Soil may be regarded as waterlogged when the groundwater table is too high by reducing soil aeration in the rootzone retarding plant growth. Waterlogging occurs mainly because of two primary causes: (1) nature and properties of the soil (e.g. black cotton soils called Vertisols); (2) inefficient application of irrigation water without proper drainage.

Ethiopia ranks third in the presence of Vertisols in Africa after Sudan and Chad (Kebede and Bekelle, 2008). Vertisols cover 12.6 Mha (10.3% of the total land), which is more than 60% of the country's highlands where traditional smallholder mixed farming systems are practiced (Jutzi, 1990). These soils have a 0–2% slope range and are usually found in restricted drainage landscapes (Debele, 1985). Despite the high potential of these soils in the highlands of Ethiopia, productivity is constrained by its limited internal drainage and severe waterlogging problems. Early planting is prohibited with traditional management systems in the north-central highlands of Ethiopia due to seasonal waterlogging during the rainy season (Erkossa et al., 2004; Kebede and Bekelle, 2008).

There are vast waterlogged and salt-affected areas in the Awash River Basin, where one-third of the country's large-scale irrigation schemes are located. Waterlogging in irrigation schemes occurs due to seepage from canals, over-irrigation of fields, inadequate surface drainage, incorrect and defective irrigation methods, etc. Waterlogging in the irrigation fields, mainly in the middle and lower Awash River Basin, is often accompanied by soil salinity. Waterlogged soils prevent the leaching of salts imported by the irrigated water. In the absence of any long-term protective measures, the waterlogged and saline areas are on the rise.

A study in the upper Awash valley by Dinka et al. (2014) has shown that groundwater table depth in the sugarcane farms is very shallow. There is also a tremendous spatial and seasonal variability in the groundwater table depth. About 90% of the farms at Wonji sugar estate have groundwater tables above the critical depth of 1.5m. The groundwater table rise was attributed to excessive irrigation and a lack of proper drainage. The groundwater table depth of the Metehara irrigation scheme in the middle Awash River Basin is also categorized as shallow (< 3 m), and significant areas of the sugarcane plantation is under severe waterlogging condition (< 1 m). This irrigation scheme is also being affected by saltwater encroaching from the salty lake Beseka. The groundwater in this area is also severely affected by the seepage of highly saline lake water (EC > 8 dS/m) (Dinka et al., 2009).

In the Amibara area of the middle Awash River Basin, the groundwater level at the start of the irrigation scheme in the late 1960s was below 10m (Halcrow, 1982; 1983), and the soils were non-saline. However, excessive seepage from the irrigation fields has caused a progressive rise in groundwater table depth and soil salinization. The rise was more pronounced in banana fields, which use basin irrigation. A study using 30 years' data by Abebe et al. (2015) revealed that the groundwater table depth in a significant portion of the farms is within 3m. Further, around 90% of the area had saline groundwater with EC > 4 dS/m. Climate is also a critical factor in the salinization process. The high temperature of the Middle Awash (annual average 26.7°C), low annual rainfall (500 mm), and increased free evaporation of water have aggravated the salinization process (Ayenew, 2007). Furthermore, large areas in other parts of the country are similarly affected by waterlogging and salinization mainly because of improper irrigation water management.

05

IRRIGATION PRACTICES IN THE SALT-AFFECTED AREAS

5.1 Soil salinity and sodicity

Soil salinity is a measure of the concentration of all soluble salts existing in soil water. It is generally expressed as the electrical conductivity of the saturated soil extract (ECe). The major soluble mineral salts are the cations of Sodium (Na), Calcium (Ca), Magnesium (Mg), Potassium (K), and the anions of Chloride (Cl), Sulfate (SO4), Bicarbonate (HCO3), Carbonate (CO3), and nitrate (NO3). Saline soils may also contain toxic substances such as Boron (B), Selenium (Se), Strontium (Sr), Lithium (Li), Silica (Si), Rubidium (Rb), Fluorine (F), Manganese (Mn), Barium (Ba), and Aluminum (Al) (Tanji, 1990).

Soil sodicity accumulates sodium relative to other salt cations, especially Calcium. This causes an increase in soil pH and a decrease in Ca and Mg salts. Sodic soils are characterized by a poor soil structure, low infiltration rate, poor aeration, and are difficult to cultivate. They contain clay that swells and disperses when wet; dispersion shows a refined clay suspension in the soil water (Wiesman, 2009).

5.2 Causes of Soil salinity and sodicity

The most common sources of salts in soils are the following (Zaman et al., 2018).

- Inherent soil salinity (weathering of rocks, parent material)
- Use of brackish and saline irrigation water
- Seawater intrusion into coastal lands as well as into the aquifer due to over
- Overuse of freshwater for irrigation
- Restricted drainage and a rising water-table
- Surface evaporation and plant transpiration
- Seawater sprays, condensed vapors which fall onto the soil as rainfall
- Windborne salts yielding saline fields
- Overuse of fertilizers (chemical and farm manures)
- Use of soil amendments (lime and gypsum)
- Use of sewage sludge and/or treated sewage effluent
- Dumping of industrial brine onto the soil

5.3 Soil salinity problems in Ethiopia

Salinity is one of the severe devastations due to mismanagement of irrigation and aridity (Shahbaz and Ashraf, 2013). In such areas, salinity develops due to poor soil management and often due to improper management of irrigation water. Excessive salts (high salinity) in the root zone will reduce water uptake and cause nutrients to unbalance, affecting plant growth and yield. A high concentration of specific ions can also become toxic to crops. The fertility and salinity status of Ethiopian soils (in regions of intensive cultivations) have declined and continued to decline, particularly in low soil nitrogen availability excess soluble salts posing a challenge to crop production. The nutrient mining of the soils might be caused by the losses of soil organic matter, macronutrient, micronutrient depletion, topsoil erosion, acidity, and deterioration of other soil physical properties. The effects of soil salinity are serious in irrigated fields with irrigation practices that do not consider sustainable management.

Sodicity, the presence of a high proportion of sodium ions relative to other cations, is also a severe problem affecting soil properties and thus productivity. While salinity promotes soil flocculation and sodicity causes soil dispersion. As the proportion of exchangeable sodium increases, the soil tends to become more dispersed, resulting in the breakdown of soil aggregates and lowering the permeability of the soil to air and water. Dispersion also results in a dense, impermeable surface crust that hinders the emergence of seedlings.

The soil salinity problem in Ethiopia has been causing devastating effects on agriculture in Ethiopia. Farmers are experiencing substantial crop losses, while many farms have gone out of production over the last decades (Qureshi et al., 2019). The salinity problems in Ethiopia are spread over a range of landscapes, irrigated lands, rain-fed farming areas, and rangelands. In Ethiopia, about 44 Mha (36% of the total land area) is potentially susceptible to salinity problems, of which 11 Mha have already been affected by different levels of salinity and are mainly concentrated in the Rift valley (Okubay and Manuel, 2019). The arid and semi-arid agroecology, which account for nearly 50% of the country's land area, are considered marginal crop production systems due to soil and water salinity (Qureshi et al., 2018). The salinity and sodicity problems are particularly widely spread in the country's water-scarce eastern, north-eastern, and southern parts. Lack of awareness by the farmers on the causes and remedies to the problem is considered one of the significant factors for uncontrolled expansion. With the increase of the problem, salinity will have severe consequences, affecting the country's economy and food security.

In major irrigation schemes of the country, soil salinity has been building over the years. The problem in these irrigation areas is associated with less controlled irrigation water application and poor drainage facilities. Irrigation and drainage are considered complementary; irrigation systems without adequate drainage systems would not be sustainable. Poor irrigation efficiency in the irrigation schemes results in significant deep percolation losses resulting in high groundwater levels in the fields, causing waterlogging. In addition to irrigation water, rootzone salinization is also caused by waterlogging, which brings salts to the root zone. The large-scale irrigation schemes in the Awash Basin are challenging crop production. These include Wonji sugar scheme, Upper Awash (Horizaon planation), Metahara sugar scheme, Amibara (Melka Sedi/Melka Werer), and Dubti areas.

5.4 Current irrigation practices in saline areas in Ethiopia

The impacts of salinity are particularly more pronounced in irrigated areas in Ethiopia. This is mainly because human activities such as irrigation modify the agricultural water balance and the chemical balance in the root zone. As a result, secondary salinization is evident in irrigated lands. Awash Basin is the most utilized river basin in Ethiopia for irrigation, with about 30% of the total irrigated areas by large and medium scale irrigation being in the same basin. Salinity is more severe in the Rift Valley system. So, irrigated areas in the Rift Valley (including Awash and Rift Valley Lakes basins) are the most affected by salinity. Some of these irrigated areas under salinity threats are shown in Table 7, and their potential irrigable areas are highly threatened due to salinity.

Table 7. Saline area in the irrigation schemes of different river basins.

No	Schemes	Planned areas (ha)	Actual area (ha)	River Basins
1	Ziway-Meki	12,000	4,400	Rift Valley Lakes
2	Metahara	12,800	12,000	Awash, Upper Valley
3	Amibara	16,000	8,000	Awash, Middle Valley
4	Gewane	3,000	1,500	Awash, Middle Valley
5	Dupti/Tendaho	25,000	10,800	Awash, Lower Valley

Ziway-Meki irrigation scheme is in the Rift Valley Lakes Basin, part of the central rift valley. This area is famous for growing horticultural crops such as tomato, onion, and chili through private irrigation systems and commercial schemes. The total irrigated area in the sub-basin is about 4,381 ha, making it one of the intensively irrigated corridors in Ethiopia. The oldest irrigation scheme in the area is the Meki-Ziway scheme, constructed in 1986 with a planned command area of 3,000 ha, but currently, only 222 ha is irrigated (Haile et al., 2020). There is also another irrigation scheme called Meki-Ziway to irrigate about 2,000 ha using water from Lake Ziway.

The soil salinity and sodicity problems in the irrigated farms of the central Rift Valley (Ziway and Meki areas) are related to saline groundwater for irrigation and the absence of appropriate drainage systems. Soil salinity is wide-spread in several irrigated areas in the Awash basin. The Awash River basin is the most utilized for irrigation and is the most urbanized basin in Ethiopia. As a result, pollution from both point and non-point sources is a significant concern. In addition to the deteriorating water quality due to pollution from domestic and industrial wastes, Awash River water shows severe deterioration of surface water quality along its routes. This is evident from the Awash River water salinity increases from the upstream (Koka dam) to the downstream (Dupti area).

Flow division structure with missing control gates at Meki Ziwai irrigation scheme

Expanding Lake Beseka with salty water

The irrigation schemes in the Middle Awash, mainly the Amibara scheme, are the most affected by soil salinity and sodicity. The soils of the system are highly saline, with ECe ranging from 16 to 18 dS/m in the profiles (Qureshi et al., 2018). The middle and lower Awash valley is a central agricultural corridor, particularly for industrial crops. About 64% of the total seed-cotton production of the country was produced from this area, including Amibara, Gewane and Dupti areas (Ethiopian Investment Agency, EIA). The leading causes of salinity are (i) lack of drainage systems, (ii) poor natural drainage of the soils, (iii) poorly controlled and inefficient irrigation practices, (iv) recent increases in salinity of irrigation water due to the mixing of Lake Beseka. Lack of drainage and over-irrigation has caused rising groundwater levels over the years in the irrigated farms of Amibara, causing severe waterlogging.

Amibara irrigation scheme had an irrigated area of 16,000 ha over several years since establishment. However, since the last decade, the irrigated area has shrunk faster due to mainly the effects of soil salinity and sodicity, with the current irrigated area of less than 8,000 ha. Although the irrigated area has decreased by 50%, the irrigation water diverted to the scheme has not significantly reduced, indicating a clear over-irrigation. The head regulator at the diversion is not carefully operated to match water demands with supplies. Irrigators also do little to limit excess water application at the fields, and the institutional setup to manage and use the scheme is inferior. The results of all these are threatening the sustainability of the Amibara irrigation scheme.

Salinity visible on the surface of furrows at Amibara irrigation scheme

The following are the leading irrigation and related practices and interventions causing and aggregating the salinity problems in saline areas in Ethiopia.

- **Expansion of small-scale irrigation using marginal water:** irrigation is a crucial source of livelihoods, food security, and poverty alleviation for Ethiopian smallholder farmers. As such, small-scale household irrigation practices are widely expanding. These smallholder irrigators often give little or no care to irrigation water quality as long as the water is available. Irrigation with marginal quality water is therefore commonly practiced.
- **Lack of know-how:** In several areas, particularly for smallholder irrigators, there is no clear understanding of the relationship between irrigation practices and soil salinity. The risks of poor irrigation practices on soil salinity are not well understood among the irrigators.
- **Lack of alternative water sources for irrigation:** In recent years, groundwater has hugely expanded in areas where surface water is scarce and unreliable. However, in general, groundwater is generally more saline than surface waters, posing more salinity risks.
- **Little consideration is given to irrigation water quality:** In general, little emphasis is given to water quality for irrigation starting from water sources identification to water management.
- **Lack of alternative water sources for irrigation:** Often availability of a reliable water source for irrigation is a challenge for particularly small-holder farmers. There often exist no alternative water sources, and farmers are left with no options but to use poor-quality water.
- **Drainage systems are overlooked:** Drainage systems are complementary parts of irrigation systems. However, in Ethiopia, drainage systems are generally given very little attention from planning to implementation and operation of irrigation schemes. While proper drainage systems are almost non-existent in irrigation schemes, they fail or are poorly functional in major large-scale irrigation schemes due to poor management and lack of maintenance.

- **Over irrigation:** Excess and inefficient water application is a common phenomenon in irrigated farms in Ethiopia. Farmers lack understanding of the risks of excess irrigation on soil properties and thus to crop productivity. As a result, waterlogging is observed in several irrigated farms endangering sustainability due to salinity and lack of aeration.

- **Lack of irrigation water measurement:** Matching irrigation demands with water diversions is a crucial challenge among irrigators. They lack the facilities for correctly measuring irrigation water diversions from the sources. So, irrigators rely on estimations of water diversions and continually be on the higher side if water is available.

- **Wrong use of leaching water:** Leaching is effective with drainage systems or good natural drainage of the soils. Excess water use for leaching in areas with no drainage causes rising groundwater levels, further aggravating the salinity problem.

5.5 Current irrigation practices for salinity management

There are broad soil salinity management interventions that can be adopted to reduce its extent and impacts. Wude and Mahider (2020) highlighted interventions for salinity management that fall into three categories: engineering, agronomic, and policy (Table 8). Ethiopia's irrigation practices are generally not in line with the standard irrigation management practices for saline areas. There are multiple factors for this, including policy, technical, institutional, and economic constraints. This means that irrigation practices in Ethiopia are less sustainable and need revision. On the other hand, the irrigation sector is crucial for Ethiopia’s food security and poverty alleviation; and more needs to be done to ensure the adoption of the appropriate irrigation management practices for saline areas.

Table 8. Various remedial options and interventions for soil salinity

Category	Description
Engineering	Construct additional storage facilities for water (dams and reservoirs) and salts (evaporation ponds)
	Improve maintenance of irrigation infrastructure
	Conserve water in catchment and rain in irrigated areas
	Construct drainage facilities
	Improve maintenance of existing (including natural) drains
	Reuse waste and drain water, and find alternate ways to dispose of drainage effluent, and industrial and municipal wastewater
	Management Improve the operation of existing irrigation and drainage infrastructure by introducing management information systems, etc.
	Prevent or reduce canal seepage, i.e., through the lining
Agronomic	Grow different crops or introduce different crop rotations, i.e., less-water demanding crops, more drought- and salt-tolerant ones
	Irrigate according to reliable crop water requirement estimates (yield response functions) and leaching requirement calculations
	Reduce irrigated area (use more water per unit land)
	On-farm watercourse improvement and precision land leveling
	Apply soil amendments, such as gypsum, Biochar, compost, etc.
Policy	Introduce water and power pricing to make water more expensive
	Introduce transferable water entitlements
	Set limits for allowable groundwater recharge (amount and quality) and introduce penalties for exceeding these limits.
	Provide incentives for land reclamation

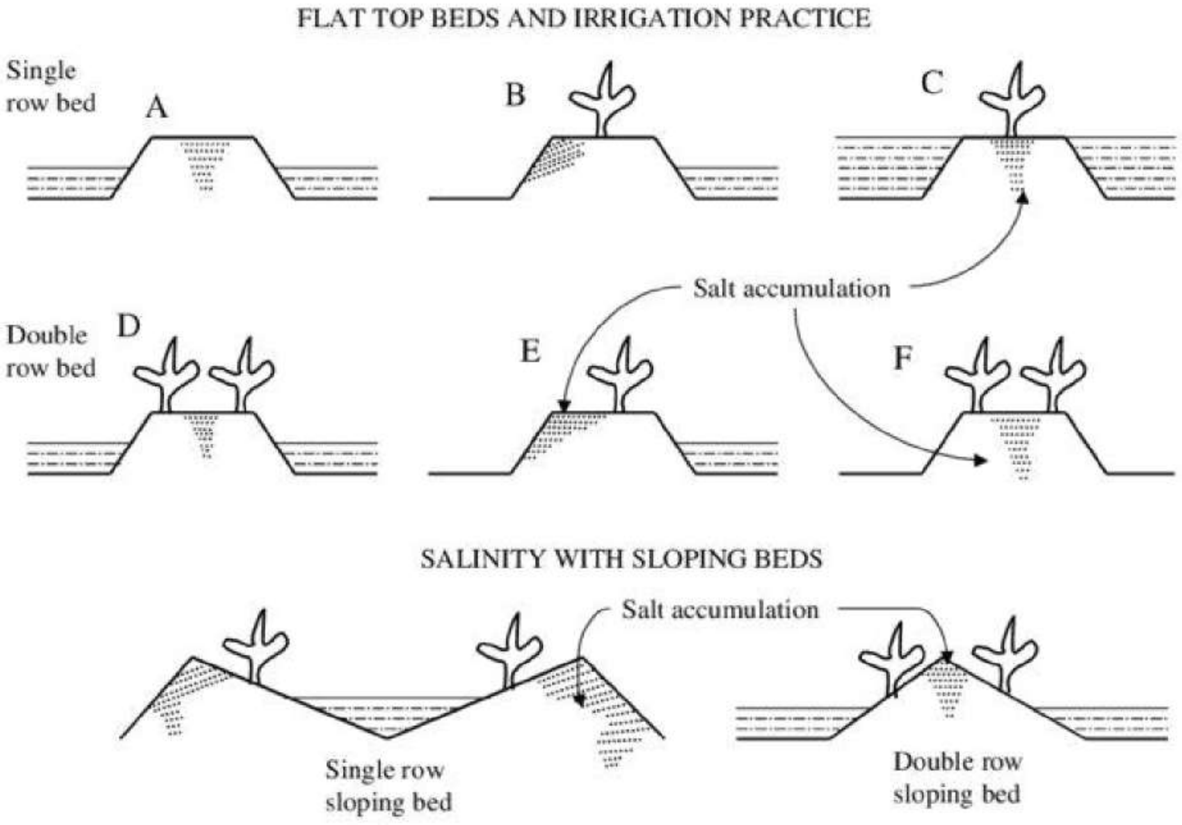
The standard irrigation practices for salinity management include, but are not limited to, the following.

Frequent irrigation application

In soils of inadequate drainage that do not allow adequate leaching of salts, more frequent irrigation can help leach out the salts from the topsoil, thereby reducing accumulation. The water application depth in each irrigation event should be reduced so that the total depth of water applied during a season matches the total irrigation demand without diminishing the leaching requirements. .

Planting on ridges in areas of low salt accumulation

Salt accumulation in surface irrigation methods (such as furrows), is higher in the top of the ridges where there is no leaching and little water contact with the soil. This means that the placement of plants in the high salt concentration areas needs to be avoided. Side ridge planting (the zone where there is frequent salt leaching) substantially reduces the effects of salinity. Re-plowing the furrowed field for each new crop will redistribute the accumulated salinity, thereby allowing continued cultivation in the area (Zaman et al., 2018).



Typical salt accumulation pattern in ridge and bed cross-section in soils irrigated by furrows

Avoiding irrigation with saline water

Irrigation is a human intervention that affects farm water balance and the chemical and physical characteristics of the soils. Irrigation with poor quality water can result in total loss of productivity in irrigated farms. In Ethiopia, water quality for irrigation is not given the required attention. Due to the seasonal water scarcity, irrigators often use water sources available for irrigation regardless of their poor quality. However, minimum standards for irrigation water quality need to be met for any water sources to use for irrigation. Otherwise, irrigation with saline water will add more and more salts to the soil, thereby deteriorating the soil properties.

Improving irrigation efficiency

Excess irrigation water application is one of the major causes of secondary salinization in areas of poor soil drainage, thereby causing rising groundwater tables and salt movement to the root zone. Most irrigation schemes in irrigated areas are characterized by low efficiency due to technological, technical, and management limitations. The efficiency of large and medium irrigation schemes is 30-50%, associated with the consequential impacts of waterlogging and salinity. It is commonly observed that framers over-irrigate their fields. This extra water diversion at upstream causes severe water shortages for downstream users within a basin. So, increasing irrigation efficiency through water-saving technological and improved management is critical to controlling soil salinity.

Leaching in good drainage soils

The classical and more widely used strategy for salinity control is the leaching of salts from the root zone. This is accomplished by occasional excessive irrigation applications with good-quality water to dissolve, dilute and move the salts. Leaching is often considered the key to salinity control and irrigation sustainability. Over time, salt removal by leaching must equal or exceed the salt additions from the applied water (FAO, 1988). However, leaching is only effective in soils with adequate natural drainage or installing drainage systems to remove the excess water used for leaching. In soils with poor drainage, leaching with an extra volume of water causes waterlogging, another more severe challenge causing land degradation by preventing aeration and moving up salts.

Provision of adequate drainage

Drainage is a complementary part of irrigation systems. A well-designed and constructed irrigation system without drainage facilities would not be complete. Waterlogging and salinity will be a threat, particularly in arid and semi-arid areas with intensive irrigation. It is the removal of excess water from the soil with surface ditches or underground pipes. In arid and semi-arid climates, a salinity problem caused by poor drainage cannot be adequately controlled until the water table is stabilized and maintained at a safe depth. This requires open or tile drains or drainage wells to remove some salty subsurface water and transport it to an acceptable salt sink for safe disposal (FAO, 1988).

In many cases on irrigation schemes in Ethiopia, drainage systems are largely overlooked. Although these exist in the designs, they are either not adequately installed or poorly managed that causes them to fail without serving the purposes. Sub-surface drainage is more effective for salinity control; however, it does not exist in Ethiopia's irrigation schemes. It was installed in the Amibara scheme over 30 years ago but has failed due to improper management. The installation and management of adequate drainage systems (sub-surface and surface) need to be emphasized.

Introduce improved On-farm irrigation methods

Field irrigation systems such as surface, sprinkler, and drip, have different impacts in controlling the salinity effects on irrigated crops. An irrigation system should ideally permit frequent, uniform, and efficient water application with a minimum percolation but without affecting leaching demand. In Ethiopia, about 98% of the land is irrigated by surface irrigation methods with poor efficiency and a high risk of waterlogging and salinity. In surface irrigation (furrows), soil salinity varies widely from the base of the furrows to the tops of the ridges. Therefore, plants shall need to be grown on the sides of the ridges or two ends of flatbeds where salt accumulation is low.

Crops irrigated with sprinklers are subject to damage from salts in the soil and salts in contact through wetted leaf surfaces. Plants with waxy leaves are less susceptible than others. When saline sprays directly contact leaf surfaces, salts can accumulate toxic levels in leaf tissue and cause decreased yields. It is also associated with leaf burn. Therefore, sprinkler irrigation with saline waters needs to be avoided for irrigation of, particularly leafy crops. On the other hand, Sprinkler systems are more efficient than surface methods in leaching out salts from the soil (FAO, 1988).

In drip irrigation, salts concentrate below and on the soil surface along the perimeters of the expanding wetting soil zone. This is due to localized leaching around the plants' emitters, and most of the roots concentrate. Drip irrigation has an advantage over surface and sprinkler systems from the point of view of soil salinity control due to: (i) drip causes no foliar accumulation of salts, (ii) salts in the wetted area of the soil are leached out, (iii) frequent irrigation in drips relatively maintains uniform soil moisture and salt levels. However, the major problem with drip irrigation is the risk of clogging if used with saline irrigation water.

Use of good irrigation water at germination

Plans are more sensitive to salinity in their germination and initial growing stage. Therefore, whenever alternative water sources are available for irrigators (such as surface and groundwater), it is recommended to use a good quality (non-saline) irrigation system in the seed germination and initial stages. For the other stages of the crops, lower quality water can be considered if this is inevitable.

Pre-planting leaching

Pre planting irrigation (excess water application) in areas where the rainfall during the off-irrigation period is not adequate for leaching out the salts offers an excellent opportunity for leaching out accumulated salts. It significantly reduces the impacts of salinity, particularly during the early stages of plant growth.

5.6 Opportunities for irrigation development in Ethiopia

Agriculture is the core and driver for Ethiopia's economic growth as well as food security. The sector directly supports about 85% of the population's livelihoods, 43% of gross domestic product (GDP), and over 80% of export value (Awulachew, 2010). Irrigation development holds significant potential to improve agricultural productivity and reduce vulnerability to climate variability and changes. Irrigation in Ethiopia could contribute up to US$ 6 billion to the economy and move up 6.0 million households out of poverty (Awulachew, 2010). Ethiopia has an essential opportunity in water-led development, but it needs to address critical challenges in the planning, design, delivery, and maintenance of irrigation systems to maximize the benefits. By doing so, Ethiopia can boost its irrigated agriculture sector to ensure food security and improve the livelihood of smallholder farmers and pastoralist communities. This transition will also enable the country to harness considerable labor resources for the operation and maintenance of small-scale irrigation schemes, creating employment opportunities while extending the reach of its water infrastructure. This intervention in small-scale schemes will enable the country to use its abundant labor to reach fragmented households and communities. The following are the rationale for developing the irrigation sector in Ethiopia (Awulachew, 2010) and own synthesis:

- Increases productivity of land and labor, which is pertinent given diminishing land hold sizes due to population growth;
- High potential for attaining food security;
- Reduced reliance on rainfall, thereby mitigating vulnerability to climate variability;
- Reduced degradation of natural resources;
- Replace imported agricultural products with local production by expanding irrigated agriculture;
- Possibility of surplus production, thereby enabling exports of agricultural products;
- Increase job opportunities in irrigated agriculture and related value chains and promote a dynamic economy with rural entrepreneurship.
- Possibility to meet raw materials for large numbers of agro-industries being established in different regions of the country.

Generally, irrigation development can tackle the following challenges faced by the country.

Over-population: Irrigation can support crop intensification through which small plots of land can produce more food. The available household labor can also be engaged throughout the year, thereby improving labor productivity. Provision of irrigation can create employment opportunities through the forward and backward linkages between irrigation and commodity value chains.

Climate variability: Climate variability, including droughts and flooding, is a major agricultural constraint of Ethiopia. Climate variability is expected to increase the occurrence and the severity of extreme events (flood and drought) and related shocks. Improved water management and irrigation can increase resilience during droughts and reduce vulnerability during environmental shocks.

Land degradation: Ethiopia's soil is estimated to be moderate to severely degraded, which decreases land productivity. Irrigation and watershed management can reverse this degradation by conserving soil and water, reducing flooding, and increasing recharge and baseflow.

Farm productivity: Ethiopia's crop productivity is frequently below potential. For instance, the average maize yield was 2.2 tons/ha compared to the 4.7 tons/ha potential. Increasing farmer productivity is crucial for improving smallholder income and livelihood. Irrigation helps improve crop productivity, primarily when used with improved inputs (e.g., seed, fertilizer).

Gender equality: Irrigation can also provide equal financial benefits to rural women, increasing their cash incomes and diversifying family nutrition and food sources. Carefully monitored must be done to ensure equal access to land and water resources to women. Participation of women in Water Users' Associations should be promoted. Irrigation can also potentially reduce the burden of irrigation labor on women.

06

SOUTH SUDAN

6.1 Geography and location

South Sudan got independence from Sudan in 2011 after a lengthy civil war and a referendum in favor of secession. South Sudan represents around 30% of the pre-2011 Sudan (FAO, 2015). It is a landlocked country bordered by Sudan in the north, Ethiopia and Kenya in the east, Uganda and the Democratic Republic of Congo in the south, and the Central African Republic in the west (Figure 13). South Sudan is divided into 28 states corresponding to Sudan's three historical regions: Bahr el Ghazal, Equatoria, and Greater Upper Nile. The country is home to around 60 indigenous ethnic groups and 80 linguistic partitions. It has a land area of 619,745 km² and a population of 11.3 million in 2013 with an annual growth rate of 4.1% (over the period 2012-13), which is the highest in Africa with a population density of 18 inhabitants/km² and 70% of the total population lives in rural areas.

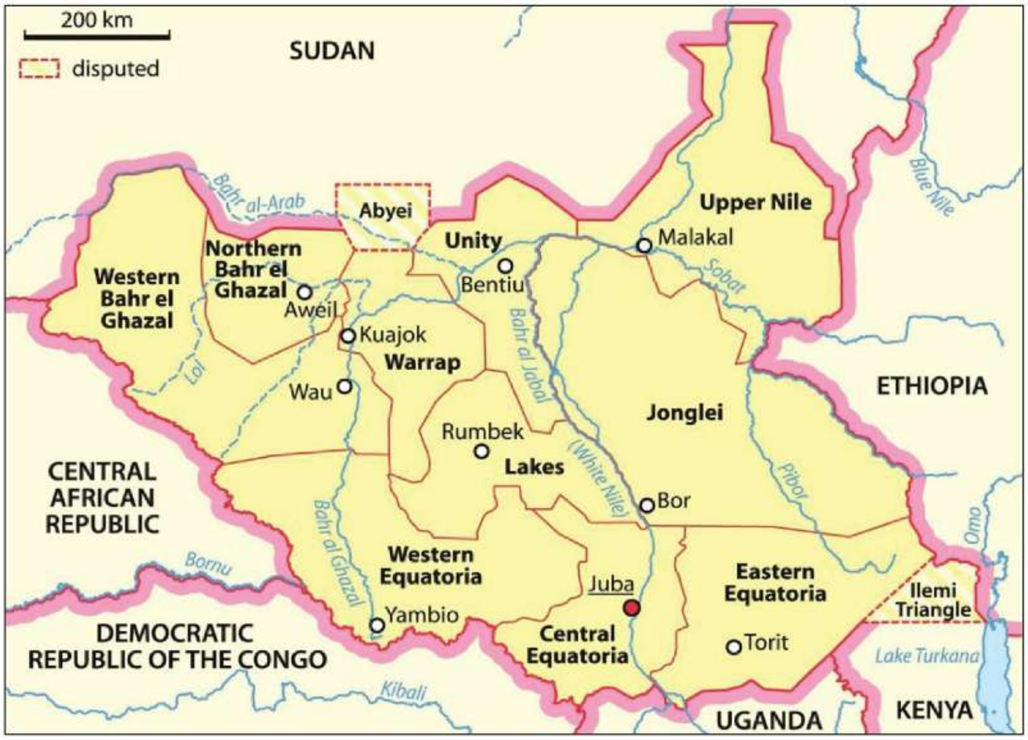


Figure 13. Geographic map of South Sudan with regional boundaries

6.2 Agriculture in South Sudan

Agriculture is the backbone of the economy of South Sudan. Estimates on value addition by agriculture, forestry, and fisheries accounted for 36% of non-oil GDP in 2010. About 80% of the population lives in rural areas, with agriculture, forestry, and fisheries providing the primary livelihood for a majority of the households in each state. Much of the rural sector activity is currently focused on subsistence agriculture instead of production for markets. Among the significant reasons for this is: (i) the need for improved agricultural inputs and techniques such as seeds and fertilizers, storage facilities and advisory services, and irrigation development; (ii) the difficulties faced by farmers in accessing markets due to the poor road network, lack of other transport modes and nuisance taxes and charges, including bribes; (iii) the lack of a critical mass of farmer and rural producer associations as a means of entering the market place to minimize the cost of inputs, access loan finance at affordable rates and influencing farm-gate prices; and (iv) uncertainties about property rights and access to land.

South Sudan is now a net importer of food. It currently imports as much as 50% of its needs, including 40% of its cereals from neighboring countries, particularly Uganda and Kenya. Total food imports are estimated to be in the range of $200-300 million a year. While the country produces and consumes a wide range of agricultural commodities, some commodities have become prominent in the national consumption pattern with time. Cereals, primarily sorghum and maize, millet, and rice, are the dominant staple crops in South Sudan. About 75% of rural households consume cereals. At the state level, the percentage ranges from 28% in Upper Nile state to 62% in Western Bahr el Ghazal and as much as 95% in Northern Bahr el Ghazal. For the country, cereal consumption accounts for about 48% of total primary food consumption in terms of value. Livestock accounts for approximately 30%, fish 4%, roots 2%, seeds about 3.8%, and other non-cereal crops combined, 12.7%..

Sorghum is the main crop cultivated with a wide range of local landraces. It is the leading staple food in all states, except for the three Equatorias, where the local diet is also based on maize flour (imported mainly from Uganda) and cassava (mainly in the Green Belt). In Northern and Western Bahr el Ghazal, Warrap and Lakes. Sorghum is often intercropped with sesame and millet. Maize is usually cultivated in limited areas, close to homesteads, and often used for green consumption. In Central and Western Equatoria, sweet potato, coffee, mango, and papaya are commonly grown. Some vegetables (Okra, cowpea, green gram, pumpkin), and tobacco are grown around homesteads. Vegetables such as onions or tomatoes are not widely grown in rural areas but are increasingly cultivated near cities to supply urban markets.

Livestock provides the primary source of livelihood for a substantial portion of the population, with herds (primarily cattle) concentrated mainly in western parts of Upper Nile State and East Equatoria, Jonglei, and Bahr El- Ghazal states. Livestock is raised by nomads and seminomads and is entirely dependent on access to grazing land and watering points. However, the increasing number of sedentary farmers is reducing the amount of grazing land available. With over 95% of agricultural production being rainfed, weather variability is significant in determining crop performance. In lowland areas, flooding is a regular occurrence, but the variability of the water levels affects harvested areas and yields. For the most part, agriculture is based on small, hand-cultivated units often farmed by women-headed households. Despite land availability for farming, manual land preparation limits the area families can cultivate. Using animal traction would allow farmers to develop larger plots and plants in line to ease weeding.

Five states account for 70% of the national cropland (and 56% of the national territory): Upper Nile, with 19% of total cropland; Warrap, 15%; Jonglei, 14%; Western Equatoria, 11%, and Central Equatoria with 11%. Almost all irrigated crops (mainly rice) are in Upper Nile; rice on flood land is all in Northern Bahr el Ghazal while fruit trees themselves into groups, cooperatives, or associations. However, many producer members do not farm as a business, and decisions are not based on cost/benefit. The actual area cultivated in any year ranged from 1% to 2% of the total land area, from 650,000 Mha to 1.3 Ma. According to FAO-WFP reports, about one million hectares were put under cultivation in 2008. Cereals typically account for 80% or more of the cultivated area each year; for example, the area under cereals in 2008 was about 850,000 ha.

The agricultural sector in South Sudan accounts for about 14.5% of the total GDP or 36% of the non-oil GDP in 2010 (AfDB, 2013). Despite having great potential, agriculture in South Sudan primarily consists of manually cultivated subsistence farming under rainfed conditions on household plots of less than two hectares (FAO, 2015). The cultivable area is estimated at 2.76 million ha (Mha) (4% of the total land area), and nearly 50% is found in Upper Nile, Jonglei, and Warrap states. The forest resources of South Sudan cover approximately one-third of the total area of the country. Natural forests are diverse, including rainfall savannah, woodlands, and the particular regions of mountainous vegetation in the Imatong Mountains, making it one of the wealthiest areas of concentrations of biodiversity in Africa. Shrubs cover around 39% of the country and herbaceous vegetation around 22% (AfDB, 2013).

07

WATER RESOURCES MANAGEMENT IN SOUTH SUDAN

7.1 Surface water resources

The River Nile is the dominating geographic feature in South Sudan, flowing across the Country. The Blue Nile and its tributaries flow down from the highlands of Ethiopia. In contrast, the White Nile and its tributaries flow from Uganda and the Central African Republic into the low clay basin to form the world's largest contiguous swamp on their way to Sudan and Egypt (The Sudd Region). South Sudan is home to the World's Largest Swamp, covering 30,000 square kilometers, e.g., the Sudd region. The surface water resources of South Sudan comprise the Nile River system and the Rift Valley basin. About 20% of the Nile basin lies within South Sudan and includes (1) the White Nile system; upstream of Sobat River originating on the Great Lakes Plateau; (2) the Baro/Sobat River system originating from the Ethiopian highlands; and (3) the Bahr El Ghazal basin, an internal basin in the west of South Sudan and extending to Sudan in the north. The Sobat and Bahr El Ghazal rivers are seasonal rivers, whereas the Nile River is perennial. The annual internal renewable surface water resources of South Sudan are estimated at 26,000 million m³ per year. The major waterway network of South Sudan is Shown in Figure 14, and the detailed characterization of these rivers is given in Table 9.

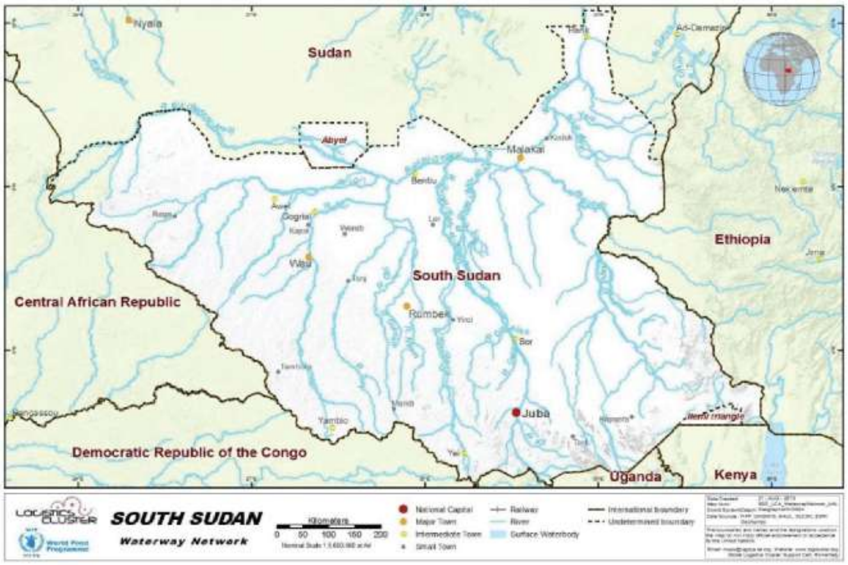


Figure 14. Waterway network of South Sudan

The potential irrigation development in South Sudan has been limited due to technical and financial constraints. However, over the last five years, the government has taken serious steps to increase the irrigated area boost agricultural production for the increasing population. Based on the water availability from these rivers, the potential of irrigation development is shown in Figure 15.

7.2 Groundwater resources of South Sudan

The primary groundwater formation in South Sudan is the Sudd basin, also known as the Umm Rwaba basin. Its extent and its relationship with the overlying surface water are unknown (FAO 2015). The Sudd is the only Ramsar-listed wetland in South Sudan (Figure 16). It is an inland delta of the White Nile and comprises lakes, swamps, marshes, and flood plains. Its extent fluctuates from 10,000 km² to more than 35,000 km² depending on rainfall and evaporation, which is exceptionally high. An estimated 50% of the inflow to the Sudd, mainly through the White Nile system, is lost to evaporation. It is one of Africa's most extensive swamps. Internal renewable groundwater resources are estimated to be 4,000 million m³ per year, which is considered to be overlap feeding the base flow of the river system.

Table 9. Characterization of main rivers in South Sudan.

River	Length (km)	Drainage area (km^2)	Outflow	Countries in the drainage basin	States in the drainage basin
White Nile River	3700	18,00,000	Confluence with Nile River	South Sudan, Uganda D. R. Congo, Sudan, Tanzania, Rwanda,	Eastern Equatoria, Central Equatoria
Bahr al-Ghazāl River	716	851,459	Joins White Nile	South Sudan, Central African Republic	Warrap, North Bahr el Ghazal, West Bahr-el-Ghazal
Sobat River	354	225,000	White Nile	South Sudan	Upper Nile
Baro River	306	41,400	Pibor River	Ethiopia, South Sudan	Jonglei
Pibor River	320	10,000	Sobat River	South Sudan	Jonglei
Akobo River	434	75,912	Pibor River	South Sudan, Ethiopia	Jonglei
Bahr el-Arab	800	60,800	Bahr al-Ghazāl River	Sudan, Central African Republic, South Sudan	Bahr el Ghazal
Jur River/Sue River	485	NA	Bahr al-Ghazāl River	South Sudan	Equatoria, Bahr el Ghazal

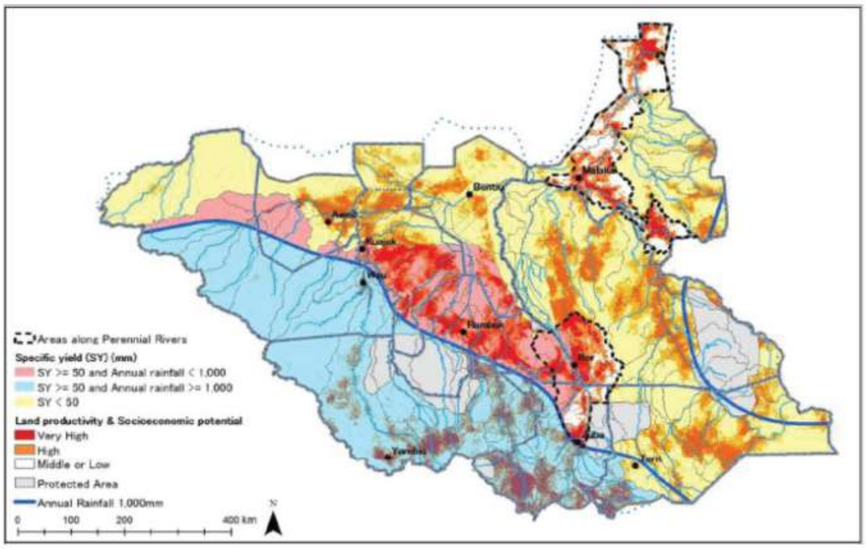


Figure 15. Irrigation potential based on surface water resources

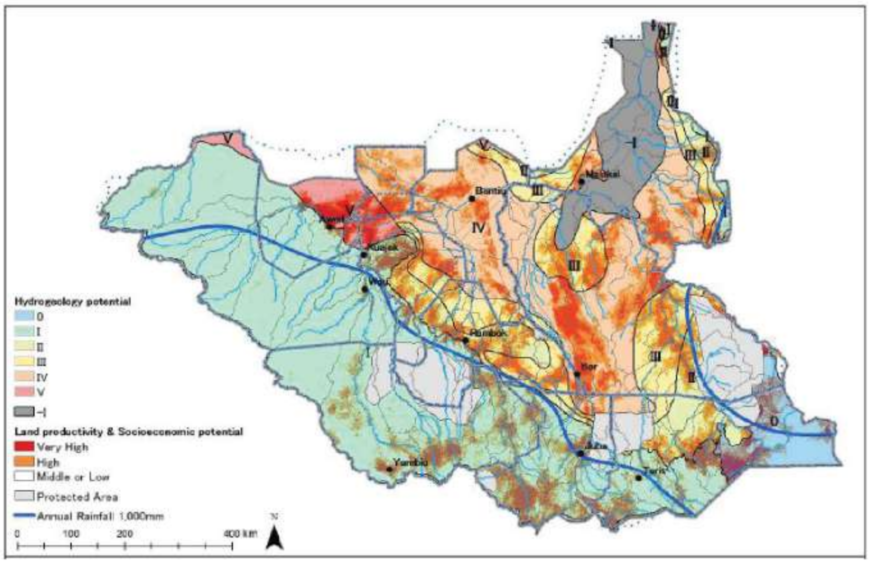


Figure 16. Irrigation potential with groundwater resources

7.3 Rainfall

The climate of South Sudan is tropical, with a hot and dry winter and a rainy summer. The predominant vegetation is the savannah, more or less arid depending on the area. Most of South Sudan has a sub-humid climate with an average annual rainfall of 900mm. It ranges between 700mm in the lowland areas of Eastern Equatoria, Jonglei, Upper Nile, and Bahr El Ghazal and 2200mm in Western Equatoria and highland parts of Eastern Equatoria (WB, 2013) (Figure 17). Depending on the region, one or two rainy seasons can be distinguished: (1) Western and Central Equatoria have a bimodal rainfall pattern from April to June and the second from August to November. This pattern creates a long-wet season, a shorter dry period (December to March), and long agriculture growing season (280–300 days). Other regions have a unimodal rainfall pattern with a wet season (May to October) and a dry period (November to April). Their annual growing season is 130–150 days.

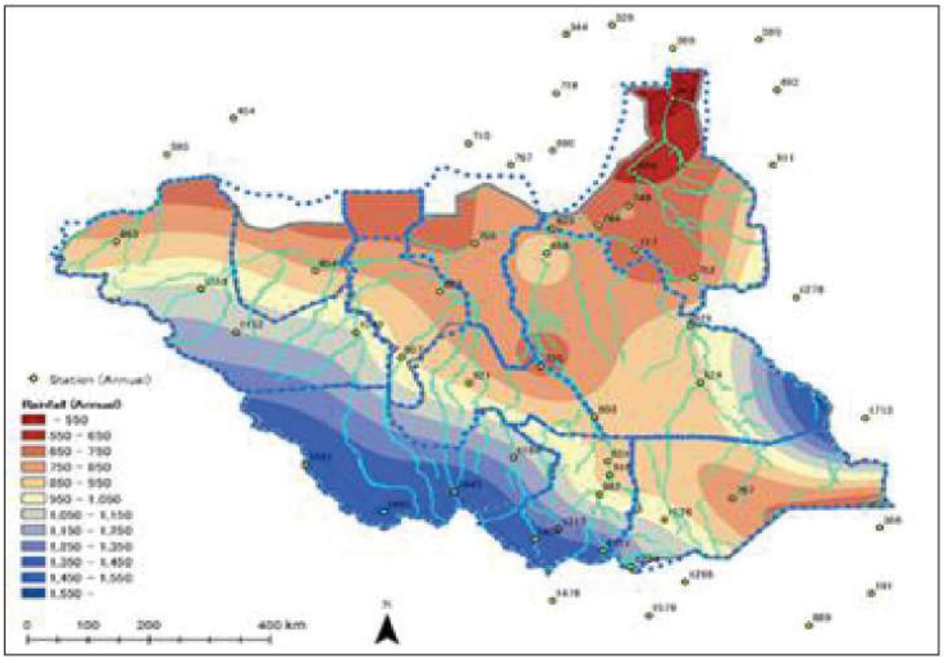


Figure 17. Rainfall contour map of South Sudan

The mean temperatures are above 25°C and can rise to 35°C, particularly during the dry season, which lasts from January to April and triggers the migration of pastoralists. In the Hills, there are two rainy seasons, April to July and August to December. As a result, potential annual evaporation decreases from 2400mm in the north to 1400mm in the south. Due to climate change, total yearly rainfall in South Sudan is declining, although not significant (WB, 2011).

The driest areas are the extreme south-east, on the border with Kenya (where we find the Ilemi triangle, an area disputed with Kenya and Ethiopia), and the extreme north-east, on the border with Sudan; in both regions, rainfall drops below 700mm per year. On the contrary, in the far south-west, near the border with Congo, annual precipitation is 1,500mm. The temperature drops with increasing altitude, and on the summit, it's pretty cold all year round.

08

IRRIGATION DEVELOPMENT IN SOUTH SUDAN

There is no recorded history about the start of irrigation in South Sudan. Indigenous communities practiced small-scale irrigation for several hundred or thousands of years. Natural flushes during rainy seasons were used to irrigate grazing lands, while some communities attempted to efficiently control the water for crop production. For example, Latuka tribes in the Imatong and Lango areas and many other regions used traditional irrigation for crops.

Based on Sudan's share from the Nile waters (as measured at Aswan dam in Egypt) and the Nile waters agreement with Egypt in 1959, the area designated for irrigation development in South Sudan is approximately a total of 1.95 Mha (4.68 million feddens). This includes large-scale schemes on modern basis and small-scale schemes that include traditional irrigation holdings. Before the second war broke out in 1983, the overall plan for irrigation development in Southern Sudan was to irrigate about 270,000 ha of land. Because of the ensuing conflict, these plans were not realized, and there has been no significant development of the country's irrigation potential. The current area of irrigated crop area is negligible, occupying only 32,100 ha – less than a tenth of one percent of national land space. About 12,700 ha of the irrigated cropland in South Sudan is in Upper Nile state; irrigated areas in Jonglei and Western Equatoria states are 300 and 500 ha, respectively, with the remaining 18,600 ha in small parcels of land across the country. In addition, about 6,000 ha of flood land, confined primarily to Northern Bahr el Ghazal, is used for rice production. Eastern Flood Plains has most of the irrigated cropland by livelihood zones, followed by the Green Belt and Nile Sobat River Basin.

Agriculture is predominantly rainfed, with annual rainfall rising from north to south and from east to west. It ranges from less than 500 mm/year in the semi-arid lands of Eastern Equatoria to about 1,800 mm/year in the Green Belt zone. Agricultural performance consequently varies considerably from place to place and year to year, ranging from the possibility of two harvests per annum in Greater Equatoria between Tambura and Kejo-Keji to one crop in the unimodal areas further north. Currently, the size of cultivable land that could be brought under irrigation by smallholders and commercial farming in South Sudan is estimated at 1.5 Mha (AfDB, 2013). This potential is divided between the Nile-Sobat river basin, Western and Eastern Flood Plains, Mangalla, and Green Belt zones. The Green Belt zone's agricultural production usually exceeds subsistence level, so modern irrigation techniques could further increase the production (AfDB, 2013).

The development of modern irrigation schemes in South Sudan started in the middle of the 20th Century during the British Colonial era. The major irrigation schemes developed during that time include the Aweil Irrigation Rice Scheme (AIRS) and the Northern Upper Nile Irrigation Schemes (NUNIS). Mongolia-Gemmeiza sugar plantation was also a planned large-scale irrigation scheme. Another study called "Natural Resources and Development Potential in the Southern Provinces of Sudan" was carried out just before the independence of Sudan in 1954. Following the investigation, some areas were already operating under pump irrigation schemes to grow cotton between Geiger and Gelhak in the Northern Upper Nile. The large-scale commercial sugar plantation in the Mongalla-Gemmeiza area was under investigation. However, the operation and implementation of those irrigation schemes remained suspended during the period of civil unrest.

Mongolia-Gemmeiza sugar plantation has been abandoned, and there is no existing schedule yet for its revitalization. Furthermore, pump stations in the Northern Upper Nile irrigation scheme have stopped working due to high operational costs and lack of appropriate repair and maintenance. As a result, farmers in the area are still cultivating small-scale farmlands mainly by using rainwater. Albeit many issues remain to operate the scheme fully, AIRS has been reactivated with the assistance obtained from the EU and executed by GIZ-IS from 2007. It was handed over to the government of South Sudan in 2012. Since then, the government has rectified technical and management problems for efficient and effective functioning of the scheme but has not yet completed it.

The sequence of events that happened with this scheme since its inception in the 1940s is presented in Table 10.

Table 10. History of the Aweil Irrigation Rice Scheme development in chronological order.

Year	Event
1945	British Government Colonial Administration initiated the scheme with four feddan.
1947	The Rice production area was extended to 21 ha (50 feddan).
1953	The scheme was taken over by the Sudanese Government: 210 ha (500 feddan).
1961-69	Flood protection dikes were built to enclose 4,600ha (11,000 feddan).
1974-78	FAO / UNDP Aweil Rice Project / Land Development Project aimed at 550 ha (1,300 feddan) with improved water control.
1979-83	EEC Aweil Rice Development Project was implemented. The area under fully controlled water management was extended to around 1,100 ha (about 2,700 feddan).
1983	The Scheme was closed in 1983, and the plan of expanding the cultivated area to 2,240 ha (5,330 feddan) was not realized.
2007–12	EU / GIZ Aweil Irrigation Rehabilitation Project was implemented. Three basins (No. 7, 8, and 9) with a total of 1,150 ha (2,700 feddan) were rehabilitated.
2012-13	495 ha (1162 feddens) were allocated to 562 farmers. Some private farmers are also cultivating in basin 15.

(Source: Kaindi (2009); Jacobsen (2011); and AIRS Annual Report 2012-2013; interviews to AIRS by IEMP-TT)

A comprehensive irrigation enhancement plan for South Sudan to irrigate about 270,000 lands was developed before the 2nd civil war in the 1980s (AfDB, 2013). However, the development of irrigated agriculture was constrained because of the instability, except for a few formal irrigation schemes constructed in the 1970s as pilot agro-industrial projects (GoSS, 2013). The current area equipped for complete control irrigation is only 38,100 ha: (1) 12,700 ha in Upper Nile state, including the Renk scheme of about 2,000 ha in Gaiger, Magara, and Abu Khadra, where cotton, sunflower, and other crops are irrigated; (2) 300 ha in Jonglei state and 500 ha in Western Equatoria state; and (3) the remaining 18,600 ha small parcels of land across the country. In these individual schemes, farmers use simple water-lifting techniques to lift water from rivers to support perennial fruit and vegetable production. In addition, about 6,000 ha of spate irrigation, confined primarily to Northern Bahr el Ghazal, is used for rice production (AfDB, 2013). Generally, despite rich water resources, only 5% of the total area is irrigated due to a lack of irrigation infrastructure. Irrigation is mainly done using surface irrigation methods, and irrigation efficiencies are as low as 30-35%

The studies done in South Sudan have shown great potential to increase irrigated areas using surface and groundwater resources if the proper infrastructure is provided. Irrigation plays a critical role in traditional farming systems to secure food supplies, especially drought-prone areas (GoSS, 2013). In the floodplain areas, irrigation is traditionally used in small vegetable gardens cultivated with additional water from hand pumps, storage ponds, or lakeside moisture. In the wet season, floodwaters are diverted into rice and sugarcane fields, and bananas are grown on the dikes protecting fishing camps and lowland settlements.

In the dry season, vegetables and tobacco are irrigated along the river through manual and minor pump-driven lift irrigation, and maize and cowpea are grown using receding floodwater. Currently, the main irrigated crops are rice, fruit trees, and tree plantations. Two harvests are possible each year in the bimodal rainfall area of Western and Central Equatoria, where the growing season is long. Still, generally, only one crop is viable in the unimodal rainfall areas further north except where water is readily available for irrigation (GoSS, 2011).

09

CHALLENGES OF IRRIGATION MANAGEMENT IN SOUTH SUDAN

Given the country's rich land and water endowment, the potential for irrigated agriculture is significant. By expanding irrigation, South Sudan can significantly increase agricultural production. The Ministry of Water Resources and Irrigation (MWRI) has identified irrigation as a means for attaining food security and addressing the problems of recurrent droughts and periodic floods. The locations for potential irrigation development include the following: (i) the lowlands, where farmers make use of flooding to supplement water for growing rice; (ii) areas adjacent to river floodplains, where farmers cultivate short-maturing varieties of sorghum; (iii) areas around swamps/marshes where extension of the growing season is possible by planting in moist soils left by receding floods; (iv) drought-prone eastern mountainous semi-arid areas with low water storage and infiltration capacity; and (v) southwest and western (Green Belt zone) whose agricultural output usually exceeds subsistence level and where modern irrigation techniques can further increase agricultural production, enhance food security and supply agro-industries.

The choice of locations for irrigation development should be guided by the prospects and potential to increase cropland and cropping season. This includes areas where unutilized arable can be converted to cropland using irrigation schemes. The analysis of the classification of aggregated land use in South Sudan shows that 27% of existing cropland is located in areas where the farm potential is high. In comparison, 42% is in areas with medium to low farm potential. Furthermore, as underscored earlier, the areas with medium to low farm potential have high population densities. On this basis, the best opportunities for expanded smallholder and commercial irrigated-based agriculture appear to be in parts of the Eastern and Western Flood Plains, the Nile-Sobat Rivers area, and the Green Belt zone. Nile-Sobat River Basin Irrigation Schemes.

The potential area that can be irrigated in the Nile-Sobat River Basin is about 654,700 ha. On average, the annual rainfall in the Basin area is between 200 to 400 mm. However, with the introduction of irrigation, the area acquires enormous potential for increased agricultural production. Development of this potential would significantly contribute to agricultural output, enhance food security and boost export earnings. It is anticipated that cereals (sorghum, rice, maize), oilseeds (groundnuts sesame, sunflower), and gum acacia would feature prominently in these programs because of the suitability of a soil as well as the great unmet domestic, regional, and global demand for these commodities. Along with the introduction of large-scale commercial irrigation, there are opportunities for the development of small- to medium scale irrigation schemes (primarily for production of rice and possibly sugar cane) in the following areas of the Nile-Sobat Basin:

In South Sudan, water management is impaired due to a lack of water data and information for surface water and groundwater resources (WB, 2013). No formal system for allocating water resources to different sectors or users exists, apart from customary laws (USAID, 2012). This sometimes leads to disputes between farmers and pastoralists, who travel considerable distances depending on water availability despite intense competition in the dry season. A water information system called South Sudan Water Information Clearing House (SSWICH) was established in 2011. The purpose of this was to systematically gather information about water to assist in decision-making at all levels of the water sector (WB, 2011).

In South Sudan, water user associations (WUAs) are not formed to regulate water allocations to farmers and routine repair and maintenance. These organizations were not even developed in the Aweil rice scheme during its rehabilitation, although they were planned (FAO, 2013). This causes an uneven distribution of water to different users and low crop productivities. In addition, lack of ownership of irrigation schemes results in poor maintenance with consequences on reduced life and efficiency. Lack of interest from government organizations further complicates the problem.

The 2011 Transitional Constitution of the Republic of South Sudan lists water among the natural resources that the government must “protect and ensure the sustainable management and utilization” together with land, petroleum, minerals, fauna, and flora (GoSS, 2011b). The 2007 Water Policy distinguishes water resources management, rural water supply, and urban water supply. Other water-related policies have been drafted or are currently under preparation. Still, the only water-related law approved after independence is the 2011 Urban Water Corporation Act which deals with water supply and public water utility (FAO, 2015). Further, the water, sanitation, and hygiene (WASH) strategic framework prepared in 2011 recommends the establishment of a Water Council as an advisory board and a Water Resources Management Authority to enforce regulatory functions.

In South Sudan, the responsibilities in water management and irrigated agriculture are shared between the following three Ministries: (1) the Ministry of Electricity, Dams, Irrigation and Water Resources (MEDIWR); (2) the Ministry of Agriculture and Food Security (MoAFS); and (3) the Ministry of Lands, Housing and Physical Planning (MLHPP). At the state level, Ministries of Agriculture, Animal Resources, and Irrigation (MAARIs) have been established along with the water and sanitation directorates. In addition, the South Sudan Urban Water Coordination (SSUWC) is responsible for developing access to improved water supply under the responsible Ministry. As a result, the institutional water sector is challenged by a lack of clarity for respective missions between MEDIWR and MLHPP and by weak capacity at the state level regarding the availability of qualified staffing, equipment, management, and operational systems. The ambiguity in roles and responsibilities of different Ministries needs to be resolved to improve the country's groundwater and surface water resources management.

There is a critical environmental concern in South Sudan related to water resources and their management. Water levels in rivers decrease due to increased erosion and siltation caused by land-use changes and overexploitation: forest clearing, over-grazing, and fires (USAID, 2012). Former permanent rivers became seasonal in the last decade, especially Lol, Jur, Gal, and Peyia rivers found along the border with the Central African Republic. A drop in the groundwater table is also observed in Northern Bahr el Ghazal State (AfDB, 2013).

Furthermore, there are punctual salinity issues in the groundwater around Malakal and isolated villages (WB, 2011) and water pollution from industrial oil wastes in Unity and Upper Nile states. However, the primary pollution is caused by the lack of improved sanitation and the absence of collection and treatment of wastewater. Most domestic wastewater and untreated excreta are carried directly into rivers and boreholes, polluting surface water and groundwater, often used for drinking and cooking. Discharged water contains fecal coliforms, causing water-borne diseases such as cholera.

The private investment in the development of small-scale irrigation in South Sudan is negligible. In addition to the economic constraints of smallholder farmers, existing land tenure laws also restrict farmers from investing in small-scale irrigation development. Furthermore, several provisions in the current land law prohibit foreigners from owning land in South Sudan. Under the 2009 Land Act (i) foreigners are not permitted to own land in South Sudan; they can, however, conditionally, lease land (for a maximum of 99 years); (ii) community lands may be allocated for investment purposes, but that investment must reflect an "important interest of the community" and contribute to the economic and social development of the local community; and (iii) land acquisition of 250 fedans (state authorities must approve 104 hectares). If South Sudan is to transit from traditional farming to commercial farming, then access to land must be equitably liberalized. Having a uniform national land law and a clearly defined and transparent ownership right and obligations will facilitate the decision of potential foreign investors in agricultural land in South Sudan. In addition, given the predominant role that women play in farming in South Sudan, the laws must be gender-sensitive and accord women unfettered right to own and develop the land. There is, therefore, a need for the government to adopt land development policies that allow potential investors to acquire, develop land and reap the benefits of their investment in commercial agricultural land.

10

PROSPECTS OF IRRIGATION DEVELOPMENT IN SOUTH SUDAN

In South Sudan, agriculture is expected to be the single largest user of the available water resources in the future. Therefore, there is an urgent need to establish policies and strategies to promote efficient water use to meet the growing water demand for irrigation and avoid potential conflicts between competing users (GoSS, 2007). This is also important because water will be an essential component of future strategies for achieving food security and agriculture-based economic growth (FAO, 2015). The first step towards effective future water management could be assessing and mapping the water resources available to the country. Special attention is needed to evaluate groundwater resources' availability, quality, and occurrence because they are mainly untapped (AfDB, 2013).

Currently, there are some efforts to identify and map more precisely the country's irrigation potential, and a national Irrigation Master Plan was prepared to prioritize investments for the development of irrigated agriculture for the coming decade (GoSS, 2013). This master plan aimed to increase the irrigated area from 38,100 ha to 400,000 ha by 2020 (FAO, 2015). However, this plan has not been implemented due to a lack of irrigation knowledge and financial constraints. The same happened to the improvement in access to water and sanitation. According to this plan, the water supply will increase to 70% in urban areas and 65% in rural areas by 2020 (AfDB, 2013). However, this has not been achieved due to organizational and financial limitations. Finally, with the significant livestock activities and its difficulty to access water in dry periods, developing water resources for livestock is also an essential objective for the country (GoSS, 2013).

The potential area that can be irrigated in the Nile-Sobat River Basin is about 654,700 ha. On average, the annual rainfall in the Basin area is between 200 to 400 mm. However, with the introduction of irrigation, the area acquires enormous potential for increased agricultural production. Development of this potential would significantly contribute to agricultural output, enhance food security and boost export earnings. It is anticipated that cereals (sorghum, rice, maize), oilseeds (groundnuts sesame, sunflower), and gum acacia would feature prominently in these programs because of the suitability of a soil as well as the great unmet domestic, regional, and global demand for these commodities. Along with the introduction of large-scale commercial irrigation, there are opportunities for the development of small- to medium scale irrigation schemes (primarily for production of rice and possibly sugar cane) in the following areas of the Nile-Sobat Basin:

The irrigation potential suggests that about 1.5 Mha of land could be brought under irrigation by smallholders and commercial farming. The World Bank has noted that experience in Sub-Saharan countries indicates that economic returns on small-scale schemes have averaged 26% compared to 17% for large-scale systems. These results depend on keeping investment costs down to best-practice levels of $3,000 per hectare for the water distribution component of large-scale irrigation and $2,000 per hectare for small-scale irrigation. For every 100,000 hectares of smallholder and medium and large-scale irrigation brought into production at these best practice costs, the investment costs would be $200 million and $300 million, respectively. However, these studies indicate that the price of public irrigation has been excessively high. Many schemes failed to capture higher yield levels and were unable to transition to higher-value crops. Another critical consideration drawn from experience in Sub-Saharan Africa is that, in most cases, irrigation is only viable for cash crops or high-value food crops (such as horticulture). Experience has shown that the economic viability of irrigation for staple food crops is often doubtful. These concerns about financial viability, farm-level profitability, and sustainability should guide investment decisions in the decade ahead. The country's development and growth will also benefit from the enhanced use of the Nile and its tributaries as water sources for irrigation and as a means of transport. However, the country's immense irrigation potential will need to be undertaken within a national strategy for agricultural water development.

In developing this irrigation potential, a master plan for irrigation development should be prepared. The master plan will need to give particular attention to the amounts of existing or potential cropland to be brought under smallholder irrigation schemes, the amount to be developed under medium- and large-scale commercial farming, and the likely investment cost per hectare. Construction costs in South Sudan are known to be high.

This plan should include the development of 400,000 ha of irrigated agriculture. The underlying assumption is that 50% would be smallholder farm development, and 50% large-scale commercial farming linked to smallholder farmers. Assuming application of best practice investment costs, the water-related component of the program would cost $1.0 billion. The $600 million for commercial farm operations would have to be mobilized from private investment. The $400 million required for smallholder development would have to be funded from public sources using Government and donor resources. Assuming that the program is successfully implemented to produce high-value crops that yielded revenue of $2,000 per hectare, gross revenues would amount to about $1 billion per year.

This would substantially contribute to the country's GDP, employment opportunities, import and export revenues. Such a program would require mobilization from strategic international agriculture partners (SIAP) and cropland expansion. The attraction of the Hybrid model investors should aim to stimulate the development of local out-grower schemes, farmer cooperatives, and other farmer-based organizations. The SIAP investor would also be expected to contribute to modern technology and agri-business management systems and facilitate the creation of the necessary logistics, including river and rural transport infrastructure. One of the side benefits of such a program may be its impact on complementary farming systems, particularly livestock.

Several other initiatives need to be taken to strengthen the agricultural sector to achieve maximum benefits from irrigation development. These are briefly discussed below:

Fertilizer production and distribution

At present, most traditional farmers do not use any synthetic fertilizer, herbicide, or pesticide, which, in part, accounts for the low yields relative to farmers in the broader region. Therefore, the government should earmark funds for financing the establishment of a fertilizer plant and a distribution system that enables farmers and farmer-based organizations to acquire fertilizer quickly and cost-effectively.

Higher quality and more widely available extension services

Continuous training and capacity development are necessary to upgrade the competitiveness targeting agronomists, irrigation technicians, soil scientists, and extension workers. Training/skills development program may include:

- Production practices of the different grains
- Food science and practical skills in grain processing as business units
- General business skills (including farm management and finance, marketing and risk management
- Pesticide use and handling, market quality assurance, and SPS requirements
- Collection, handling, and interpretation of market and business information

Adaptive research

The sustainable competitiveness of the South Sudan cereal sub-sector will depend on its ability to adapt and adopt the latest and relevant production and processing technologies. A research laboratory that aims to commercialize such technologies will ensure that extension services provided fit together to South Sudan circumstances.

Mechanized farming equipment

Currently, approximately 80% of local production comes from small and traditional farmers. Only a tiny proportion is mechanized agriculture and limited to the Upper Nile region. Lack of agricultural mechanization has resulted in the loss of crop yields on all of the main cereals in South Sudan. The Government has purchased various models of tractors and distributed them to each of the ten states to encourage the mechanization of land preparation and other field operations. The tractors are, in principle, available for hire by farmers, farmer groups, and cooperatives at a cost ranging from 50 to 240 SDG/feddan for land preparation. Over 400 tractors have been distributed to the states since 2005. Given the limited infrastructure on the ground, there are concerns regarding the capacity to maintain these tractors locally. The Ministry of Agriculture and Forestry should scale up the acquisition and distribution of tractors and plows and the requisite comprehensive training program for operators. In this regard, selected farmers should be trained in basic tractor operations, including the mounting and setting of implements. Fully equipped workshops should also be established in the state centers, and qualified mechanics to maintain should be appointed to provide repair services to tractor owners. The government should ensure that access to these tractors is equitable and available to female farmers.

Private investment in agriculture

Achieving sustained agricultural growth will require a substantial increase in private investment in the sector. There is no up-to-date and complete information about current levels of private investment in this sector. There are two distinctly different components for the estimates of private investment. One is capital improvements on smallholder farms that are undertaken primarily with farm labor with little or no use of outside capital. The other is investment undertaken on medium- and large-scale farms funded primarily with debt or equity financing by the private investors concerned. In-kind capital expenditures by smallholders have reached about $65 million a year by 2010. Investment outlays by commercial farmers are assumed to be in the range of $20 million a year. Commercial investment in agriculture is projected to increase sharply in the decade ahead to about $600 million a year by 2020. A substantial part of this investment would come from offshore private investors, some of which would involve joint ventures with domestic partners.

Revisiting land tenure laws

Several provisions in the current South Sudan land law prohibit foreigners from owning land in South Sudan. Arguably, commercial and large-scale farming, which is essential for agricultural development, requires assessing land with an unambiguous right to develop the land. Under the 2009 Land Act (i) foreigners are not permitted to own land in South Sudan; they can, however, conditionally, lease land (for a maximum of 99 years); (ii) community lands may be allocated for investment purposes, but that investment must reflect an "important interest of the community" and contribute to the economic and social development of the local community; and (iii) land acquisition of 250 fedans (state authorities must approve 104 hectares). If South Sudan is to transit from traditional farming to commercial farming, then access to land must be equitably liberalized. Having a uniform national land law and a clearly defined and transparent ownership right and obligations will facilitate the decision of potential foreign investors in agricultural land in South Sudan. In addition, given the predominant role that women play in farming in South Sudan, the laws must be gender-sensitive and accord women unfettered right to own and develop the land. Therefore, there is a need for the government to adopt land development policies that allow potential investors to acquire, develop land, and reap the benefits of their investment in commercial agricultural land.

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CONCLUSIONS AND RECOMMENDATIONS

This report review has evaluated water resources, irrigation development, existing irrigation practices, challenges, and prospects of irrigation development and management in Ethiopia and South Sudan. Ethiopia has substantially large water and land resources that can be used for irrigation development. There are 12 major river basins, of which eight are wet, and four have little surface water resources and are termed dry basins. The total annual renewable surface water resources are about 124 Bm3, while the groundwater resources are 30-40 Bm3. However, with a population of about 110 million and per capita water resources of approximately 1,100 m3, Ethiopia is approaching a physical water scarcity threshold value of 1,000 m3/capita/year.

The irrigation potential of Ethiopia is little exploited. The total irrigation potential is about 7.5 million ha, of which only about 1.2 million (16%) is currently irrigated. The development of large and medium irrigation schemes is the responsibility of the Ministry of Water Irrigation and Energy. At the same time, the Ministry of Agriculture is responsible for the development of small-scale irrigation schemes. Of the total area irrigated, an estimated area of about 260,000 ha (about 22%) is from large and medium scale irrigation, and the remaining 940,000 ha (78%) is from small-scale and micro-irrigation schemes. The performance of existing irrigation schemes is deficient, characterized by inappropriate operation, poor operation & maintenance of irrigation infrastructure, inefficient conveyance and field irrigation systems, inequitable water distribution, low water, land productivity, etc.

The spatial and temporal variability of surface and groundwater resources is Ethiopia's primary water resources and irrigation development challenge. Temporally, about 80-90% of the surface water volumes flow in three to four months, while the other eight months experience low flows in almost all the rivers. The western part of the country, mainly comprising river basins that drain to the Nile River system, has over 80% of the surface waters, while the eastern and north-eastern parts of the country are water-scarce. Other challenges to irrigation development include financial limitations, technical and institutional inadequacy, water storage and irrigation infrastructure, socio-economic constraints such as resettlement, land redistribution problem, etc.

Soil salinity is a widespread land degradation problem in Ethiopia, highly diminishing agricultural production and productivity. The problem is more pronounced in intensively irrigated lands in the Rift Valley and Awash River basins. The irrigation practices in most irrigated lands in saline areas are not in line with standard practices for salinity management. They are poorly designed and managed surface irrigation practices in Ethiopia. Significant irrigation schemes waste a massive quantity of water with an average efficiency ranging between 30-50%, causing rising groundwater levels and aggravating soil salinity. Drainage is given less emphasis in irrigation system construction and management in Ethiopia.

The salinity risks in irrigated lands in Ethiopia are mainly associated with uncontrolled and excess irrigation water application, lack of adequate drainage facilities, and expanding use of poor quality surface and groundwater for irrigation. The risks of these practices are little understood until they cause significant loss of productivity. Several irrigation schemes in the Awash and Rift Valley lakes basins have experienced severe productivity losses due to salinity, including schemes in the Central Rift Valley and Middle and Lower Awash. Rising groundwater levels and visible salt accumulations are evident in these irrigation schemes.

The irrigation techniques used under saline conditions include ridge planting, improving irrigation efficiency, leaching, adopting more frequent irrigation, using localized drip irrigation whenever suitable to leach out salts from the root concentration areas, and pre-plant irrigation. The semi-(arid) regions are more susceptible to salinity development. It is high time to introduce suitable management interventions in saline areas to ensure sustainable irrigated agriculture in Ethiopia.

South Sudan has a substantial amount of surface and groundwater resources. The country's annual renewable surface and groundwater resources are estimated at 26 and 4 Bm^3, respectively. The internal renewable water resource comprises the Nile river system and the Rift Valley basin. The primary groundwater formation in South Sudan is the Sudd basin, also known as the Umm Rwaba basin, which comprises lakes and swamps, marshes, and flood plains.

The cultivable land brought under irrigation by smallholders and commercial farming in South Sudan is estimated at 1.5 Mha divided between the Nile-Sobat river basin, the Western and Eastern Flood Plains, the Mangalla region the Green Belt zone. However, despite rich water resources present in the country, only 5% of the total area is irrigated due to a lack of irrigation infrastructure. There were several plans for irrigation development in Southern Sudan in the 1970s and 1980s. However, because of the instability, the development of irrigated agriculture was constrained and never fully operational and is still essentially non-functional. The current area equipped for complete control irrigation is only 38,100 ha, and irrigation is mainly done using surface irrigation methods with 30-35 % efficiencies.

There are also critical environmental concerns in South Sudan related to water resources and their management. Water levels in rivers decrease due to increased erosion and siltation caused by land-use changes and overexploitation: forest clearing, over-grazing, and fires. Former permanent rivers are becoming seasonal. A drop in the groundwater table is also observed in Northern Bahr el Ghazal State. Decreasing rainfall, attributed to local environmental changes and climate change, might also explain groundwater level drops. Furthermore, salinity issues in the groundwater around Malakal and isolated villages and water pollution from industrial oil wastes in Unity and Upper Nile states.

Currently, South Sudan's water sector is also impaired by a lack of updated data and information for surface water and groundwater resources. No formal system for allocating water resources to sector or user exists, apart from customary laws. Intense competition for water in the dry season often leads to disputes between farmers and pastoralists, who travel long distances depending on water availability.

Several other initiatives need to be taken to strengthen the agricultural sector to achieve maximum benefits from irrigation development. These may include increased access to fertilizer, provision of extensive extension services, increased adaptive research facilities, enhanced private investment, increased agricultural mechanization, and modification of land-tenure laws.

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BRIEF ABOUT THE RAMSAP PROJECT

Background

Increasing salinity remains a challenge to the sustainability of irrigated agriculture in Ethiopia and South Sudan as it reduces natural biodiversity and farm and livestock productivity. The agricultural sector in Ethiopia supports 85% of the workforce. About 85% of the population living in rural areas is directly dependent on agriculture for their livelihood. Seven million smallholder farmers produce more than 95% of the total agricultural outputs, including food crops, cereals, oilseeds, and pulses. Cotton and sugar are grown in state-owned large-scale enterprises. Ethiopia also has enormous livestock resources, including cattle, sheep, goats, and camels. Despite this high biodiversity and distinctive ecosystems, Ethiopia is known as a country of famine. Food shortages are widespread, and since 1970 there have been severe famines almost once per decade.

Land degradation is considered one of the major causes of low and, in many places, declining agricultural productivity and continuing food insecurity, and rural poverty in Ethiopia. Today, Ethiopia stands first in Africa in salt-affected soils due to human-induced and natural causes. Currently, about 11 million ha (Mha) land in Ethiopia is exposed to salinity and sodicity, out of which 8 Mha have combined salinity and alkalinity problems. In contrast, the rest 3 Mha have alkalinity problems. About 9% of the population lives in salt-affected areas. The saline areas in Ethiopia are in the Tigray region and Awash River basin, and the situation is expected to exacerbate in the future due to climate change-induced factors. There is an urgent need for salt-affected soils to be restored to their production potential to produce enough food for the rising population.

In South Sudan, agriculture accounts for 36% of the non-oil GDP, with 80% of the population living in rural areas largely dependent on subsistence farming and 75% of the households consuming cereals as a prominent part of their daily diet. Despite abundant water supplies, only 5% of the total 30 million ha arable land is cultivated. Crop yields are low, which negatively affects the incomes and livelihood of poor farmers. Significant barriers are lack of agricultural inputs such as seed and fertilizer, poor advisory services, and inefficient irrigation management. Although South Sudan has the highest livestock per capita globally, with 23 million head of cattle, sheep, and goats, there is little use of improved varieties of seed or breeds of livestock. For increased livestock productivity, there is a need to introduce improved forage varieties resistant to common diseases. The salt-affected lands in South Sudan are in the White Nile irrigation schemes. These areas have hardly been utilized for agricultural production despite having great potential due to freshwater availability from the Nile. Therefore, bringing degraded lands to production is essential to ensure food security and social stability.

With a 3% average population growth in these countries, future food security and the livelihood source for a considerable portion of the population remains a challenge to the governments. Increasing the productivity of existing salt-affected lands and protecting newly developed areas from the spread of salinity is therefore of paramount importance. The smallholder farmers in both countries can increase their agricultural productivity and farm incomes if their technical and financial capacity is enhanced. They need guidance on the improved irrigation and salinity management strategies and access to modified salinity-tolerant seeds for crops and forages. Therefore, for millions of farm families in these countries, access to inputs will be a dividing line between poverty and well-being.

The areas of low to moderate salinity levels can be restored by improving irrigation and crop management practices. However, in areas where increased salinity levels have restricted the growth of normal field crops, use of Biosaline Approach could be a potential solution. This approach is based on

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[1] *The Biosaline approach was developed by ICBA, in partnership with NARS of at least eight African countries and support of international donors including IFAD, OFID and IDB.*

adaptable technology packages of salt-tolerant fodders and halophytes integrated with livestock and appropriate management systems. These integrated crop and forage-livestock feeding systems can increase resilience of small-scale crop-livestock farms, particularly in Ethiopia and South Sudan where livelihood of smallholder farmers is largely dependent on the livestock sector.

This project will devise a strategy to improve the productivity of saline soils to an economically feasible level and minimize future salinity development in these areas. The project will draw on past work's successful experiences to identify the most productive alternative crop and forage production systems, and devise a strategy for scaling up these production packages to improve livelihood of rural communities, especially women in the target areas of both countries. Through enhanced crop yields and reduced loss of land to degradation, the project will improve farmers' resilience, thereby reducing migration to cities and health problems due to stress on families suffering from the impact of salinity on their livelihoods.

Project Goals and Objectives

The project's overall goal is to attain higher agricultural productivity, food security and income for smallholder farmers, agropastoral/pastoral communities through rehabilitation and sustainable management of irrigated salt-affected farming areas of Ethiopia and South Sudan. The main objective of this project is to introduce and promote appropriate technologies and practices for rehabilitation and management of salt-affected lands in Ethiopia and South Sudan and draw lessons for scaling up.

The Target Group

The project will directly target 5,000 smallholder farmers in selected areas in Ethiopia and South Sudan who face high food insecurity due to their high dependency on marginal water and land resources. The indirect beneficiaries will be about 50,000 farmers (40,000 farmers in Ethiopia and 10,000 farmers in South Sudan) dependent on forage production in both countries with an estimated total area of about 200,000 ha (150,000 ha in Ethiopia and 50,000 in South Sudan). These targets will be achieved by producing and distributing tested crop and forage seeds, disseminating improved soil and water management practices, and training farmers and extension workers in the target areas.

The rehabilitation of degraded lands will improve the livelihood of 9% of the population of Ethiopia which lives in salt-affected areas. In South Sudan, where only 7% of 30 million ha of land is being cultivated, rehabilitation and management strategies developed under this project will open a window of opportunity for thousands of rural farmers to improve the productivity of their degraded lands and increase their farm incomes. The outcomes of this project will significantly benefit women as they will have better access to food and health facilities. The transformation of degraded lands into productive lands will also create direct and indirect job opportunities for the large young population. This will help in reducing the migration trends of unemployed youth from rural areas to urban areas.

The project will target Ethiopian highlands (Tigray, Amhara, and Afar) and lowlands (Omara and Somali), which produce 87% of cattle and 5% of its sheep and goats; however, land degradation has reduced farm and livestock productivity of these areas resulting in rural poverty. The developed crop-livestock value chain system will benefit Ethiopia because this is the largest livestock producer in Africa.

The project will target the White Nile irrigation schemes (50,000 ha area) in South Sudan. These soils have an immense potential due to the availability of fresh water from the White Nile River and its tributaries which run through 7 out of 10 states, providing ready access to an abundant water supply and river transport access for agriculture producers. However, these soils are not being cultivated for decades due to low soil fertility and the non-availability of good quality seeds for crops and forages. Currently, 18% of the land is not cultivated because of seed shortage, and 9% is due to low soil fertility. Increasing the productivity of these lands will be crucial to ensure food security for the smallholder farmers of the area.

Strategy, Approach and Methodology

This project will adopt an integrated soil and water management approach to tackle the salinity problems in irrigated areas of both countries. The project strategy would be first to diagnose the issues and then develop long-term mitigation, management, and rehabilitation strategies at the farm and regional level relevant to the problem using proven and high-level international salinity science and management. Since the rehabilitation of saline soils through engineering (drainage systems) or chemical amendments is an expensive and time-consuming process, this project will work on adaptive and mitigation approaches for rehabilitating salt-affected soils.

This project will adopt a participatory approach to conduct field trials in different parts of both countries to test the suitability of local and imported crop and forage species to rehabilitate salt-affected soils. Adaptation trials will be conducted at the Farmers Training Centers (FTCs) and volunteer farmers' plots in collaboration with the national partners. These trials will also be used for demonstration purposes before scaling up. The project team will jointly implement the best management practices for salinity control at the farm level. Smallholder farmers (especially women and young farmers) will be trained to establish seed/gene banks at the community level. ICBA has successfully applied this approach in SSA.

The project will generate and disseminate sustainable integrated crop-livestock technology packages to diversify farmers' incomes through the sale of animal products and forages to local markets, thus making the production systems economically sustainable. However, salt-tolerant forage plants are variable in biomass production and nutritional value. The available salt-tolerant forages have not been selected or managed for improved livestock production. For this reason, they need to be tested locally for their (a) edible biomass production; (b) nutritional value (i.e., the response in animal production per unit of voluntary feeding intake), and (c) the use of micronutrients and nutraceutical properties.

The project will address gender equality and social issues as cross-cutting themes in each area. The project will include the most vulnerable groups of the society to ensure that the interventions benefit poor men and women farmers and households. Since rural women play a crucial role in undertaking agricultural and livestock activities, enhancing their knowledge and capacity will be one of the main targets of this project.

Project Outcomes and Impacts

The immediate outcome will be the full implementation of new salt-affected management strategies within the pilot sites with related benefits to farming communities and land management organizations. The long-term effect will be new thinking and awareness about the new salinity management approaches and implementation of overall system reform. This, in turn, will lead to out-scaling of production packages beyond the project area through project partners, including key government organizations. The successful implementation of the above activities will increase the productivity of salt-affected lands, which will positively contribute to the country's economy and reduce rural poverty. The overall impact of the project will be revitalized agriculture in Ethiopia and South Sudan.

Scaling up Pathways

The critical element of this project is to pilot innovative test strategies and approaches for the rehabilitation and management of salt-affected soils and then "scale up' recommended technologies to reach up to a more significant number of rural poor. As discussed before, all activities of this project will be carried out with the involvement of local rural communities. Once convinced, these communities will act as the champions of change and critical drivers in the process of scaling up. For successful scaling up, policy support and institutional infrastructure is very crucial. Opportunities and constraints that may affect the scaling up process will be critically evaluated during the pilot stage. For long-term sustainability, the overall impact of the alternative production systems on the lives of the rural poor, natural resources and environment will also be reviewed.

Socio-Economic and Environmental Impacts

The project will develop modified approaches to improve water management for salinity control and demonstrate best soil management practices for different salt-tolerant crops and forages. Adopting alternative crop and forage production systems will reduce the area lost to salinity degradation, bring income to farmers, and improve the livelihood of poor rural communities, especially women. The transformation of salt-affected lands into productive lands will also contribute directly to poverty reduction by increasing fuelwood, construction materials, wild foods, and medicinal plants.

ABOUT THE INTERNATIONAL CENTER FOR BIOSALINE AGRICULTURE (ICBA)

ICBA is a not-for-profit, international center of excellence for research and development in marginal environments. It was established in 1999 through the visionary leadership of the Islamic Development Bank (IDB), the Organization of Petroleum Exporting Countries (OPEC) Fund, the Arab Fund for Economic and Social Development (AFESD) and the Government of United Arab Emirates. The host country, through the Ministry of Climate Change and Environment and the Environment Agency – Abu Dhabi extended the agreement with IDB in 2010 and increased their financial support to the Center.

ICBA originally focused on the problems of salinity and using saline water for irrigated agriculture. Over the last 15 years, ICBA has evolved into a world-class modern research facility with a team of international scientists conducting applied research to improve the well-being of poor farmers in marginal environments. In 2013, the Center developed a new strategic direction addressing the closely linked challenges of income, water, nutrition, and food security. The new Strategy takes innovation as a core principle and identifies five innovations that form the core research agenda: assessment of natural resources; climate change adaptation; crop productivity and diversification; aquaculture and bioenergy, and policy analysis. ICBA is working on a number of technology developments including the use of conventional and non-conventional water (such as saline, treated wastewater, industrial water and seawater); water and land management technologies; remote sensing and modeling for climate change adaptation.

ICBA is a unique institute with a clear mandate and capacity to work on the rehabilitation of salt-affected lands. ICBA is custodian of the world’s largest collections of genetic resources of crops and forages suitable for salt-affected lands with a proven capacity of seed development and seed multiplication for variety of environments. In addition, ICBA’s long history of working in Africa with local partners makes it fully qualified and eligible to lead this project.

The International Center for Biosaline Agriculture (ICBA) is implementing a 4-year project on the "Rehabilitation and management of salt-affected soils to improve agricultural productivity (RAMSAP)" in Ethiopia and South Sudan. The project is funded by the International Fund for Agricultural Development (IFAD) and is being implemented with the technical support of the Ministry of Agriculture (MoA), Ehiopia and the Directorate of Research and Training (DRT), South Sudan. The project is of great importance for both countries as it directly targets resource-poor smallholder farmers, especially women and children, who face high food insecurity due to their dependence on marginal soils. The project is introducing innovative soil and water management practices and salt-tolerant genotypes of food and forage crops that have the potential to grow in marginal areas. In addition, scientists, extension workers and farmers are being trained to improve their capacity for the management of marginal resources. Through improved crop yields and reduction of loss of land to degradation, the project empowers farmers by increasing their resilience against the impact of salinity on their livelihoods.

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