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*Review*

# Review on participatory small-scale irrigation schemes and small-scale rainwater harvesting technology development and its contribution to household food security in Ethiopia

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**This review aims to compile the past, present and future trends of participatory small-scale irrigation schemes (PSSIS) and small-scale rainwater harvesting technology (SSRWHT) development to ensure household food security in Ethiopia. It discusses the Ethiopian PSSIS and SSRWHT development based on the historical backgrounds, current conditions of development and its contributions to the national economy, challenges and opportunities, and future development perspectives. PSSIS and SSRWHT development *has been suggested to be a central key part in curbing food scarcity and alleviating poverty not only* in water scarce regions of the Ethiopia *but also in many other developing countries.* Government, donors and NGOs are investing in developing irrigation systems, especially on PSSIS and SSRWHT. Still irrigated land is 5 to 10% of 5.3 million hectares of irrigated potential area of country. This review indicates that, the existing current performance of PSSIS and SSRWHT development in Ethiopia is not significantly contributing to national economy of the country, when compared to rain-fed agriculture. Accordingly, irrigation sub-sector is not contributing its share based on the resources potential of the country. There is no consistent and reliable inventory data, lacks agreed reports in common consensus and well-studied and documented with regards to water and irrigations related potentials and implementations of PSSIS and SSRWHT development in the country.**

**Key words:** Eco-efficient schemes practices, irrigation users' cooperative, smallholder farmers.

## INTRODUCTION

The population of the arid and semi-arid land in sub-Saharan Africa is amongst the poorest and most vulnerable people in the world. With a population of about 100.8 million which increases annually at about 2.7%. Ethiopia is the second most populous country in Sub-Saharan Africa only after Nigeria. Sub-Saharan Africa is water abundant, but uses less than 2% of its total renewable water resources. Ethiopia's geographical and

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climatic attributes provide a greater amount of rainfall than the rest of Africa on average (Amede, 2014). High population growth increases pressure on limited and fragile land resources and leads to unsustainable resource exploitation, resulting in environmental damage. If crops fail, subsistence farmers have few or no alternative means to provide food for their families. When they run out of alternatives, the poor are forced to exploit land resources, including fragile ones for survival, and inevitably, they become both the victims and willing agents of environmental degradation and desertification. In general, high level of chronic poverty contributes to low adaptive capacity to drought and threatens the lives and livelihoods of the poor more than other social groups. An increase in vulnerability to drought hazard may result from an increased frequency and severity of drought, increased societal vulnerability, or a combination of the two. Currently, the ongoing recurrent effects of drought, water scarcity, stress, vulnerability and erratic rainfall are the most urgent food security aid facing in the arid and semi-arid land regions of Ethiopia as compared to Africa is shown in Figure 1 (Bekele Shiferaw et al., 2014).

The majority of population directly or indirectly engaged in agriculture where around 95% of the country's agricultural output is produced by smallholder farmers (FAO and IFC, 2015). The vast majority of these farmers are smallholders. In that regard, smallholder farmers are that holding land not more than 1ha. These idiosyncratic shocks to agricultural production are closely linked to the persistence of poverty in the all rural of Ethiopia (FAO and IFC, 2015). Consequently at this time the Ethiopian government is trying to transform from traditional and manual, rain-fed, supply driven and production oriented agriculture to technology intensive and mechanized, irrigated, market oriented agriculture, via full packages of value addition and postharvest technologies (Gebremariam and Ghosal, 2016). The Ethiopian government considers irrigated agriculture as a primary engine of economic growth and plans to increase the current level of irrigation infrastructure three fold by the end of 2020 (Gebremeskel Haile and Kebede Kasa, 2015).

Ethiopian government has made a huge investment to developing participatory small-scale rainwater harvesting and small-scale irrigation schemes (SSWHT and PSSIS) program as a strategy to solve the household food insecurity problem of smallholder farmers. SSWHT and PSSIS program is a policy priority in Ethiopia for rural poverty alleviation and transformation growth (Gebremariam and Ghosal, 2016; Gebremeskel Haile and Kebede Kasa, 2015). Currently, SSWHT and PSSIS program is being prioritized recently as one of the best alternatives for reliable and sustainable food security, income generation, livelihood improvement, adapting to climate change and development as a whole (Mesfin and Nahusenay Teamer Gebrehiwot, 2015). Hence, there appears to be a relatively high potential for enhancing food security and poverty reduction via revitalizing SSWHT and PSSIS program performance and productivity (Bekele and Ayana, 2011). These have enabled smallholders to diversify their farming systems and grow high value crops for urban and even international markets. Smallholder farmers are the largest group of poor people in Ethiopia. However, smallholder farmers (low-income households) typically do not have access to appropriate and affordable irrigation technologies and rely on ineffective irrigation techniques. Over half of Ethiopia's 64 million rural populations live in poverty (Gebremariam and Ghosal, 2016; Bekele and Ayana, 2011).

Using these programs, smallholder farmers in arid and semi-arid land regions of Ethiopia have been producing different crops under traditional SSIS for a long time. The diversion of perennial streams using temporary structures during the dry season is the major means of irrigation. Spate irrigation of lowland valleys using runoff from upper catchments and spring development is also practiced. In Ethiopia, most of the tanks/ponds (PVC plastic) are situated in all regions, with the largest concentration found in the arid and semi-arid land regions of Ethiopia (Abraham et al., 2015).

In spite of a generally good understanding of SSWHT and PSSIS for improving food security, little is known about the detailed ways of this program development system in the Ethiopia. Although, there is no consistent, reliable inventory, well-studied and documented information with regarding to this area. This shows there is a scanty of detail study in the in the arid and semi-arid land regions of the Ethiopia. This knowledge goes important in such a way that the people and government who are living today become aware of what the people and governments in the past had done in this sector. This review is therefore important for understanding what was done in the past and what is going on now and the future in improving food security and livelihood of rural households via SSWHT and PSSISdevelopment in Ethiopia.

## EVOLUTION OF SSWHT AND PSSIS DEVELOPMENT IN ETHIOPIA

The Ethiopian Government started formal PSSIS in the early 1980s following the widespread drought that affected the country. PSSIS was given little attention during the Derge regime. It was only in the second half of the 1980s as a result of devastating famine of 1984/85. According to Mesfin and Nahusenay Teamer Gebrehiwot (2015), Bekele and Ayana (2011) and Abraham et al., (2015) report, the total potential irrigable land area in Ethiopia is estimated to be around 5.3 million hectares (Mha). From this total potential irrigable land area, 3.7 Mha by gravity-fed surface water, 1.1 Mha by groundwater potential and gently sloping areas, and

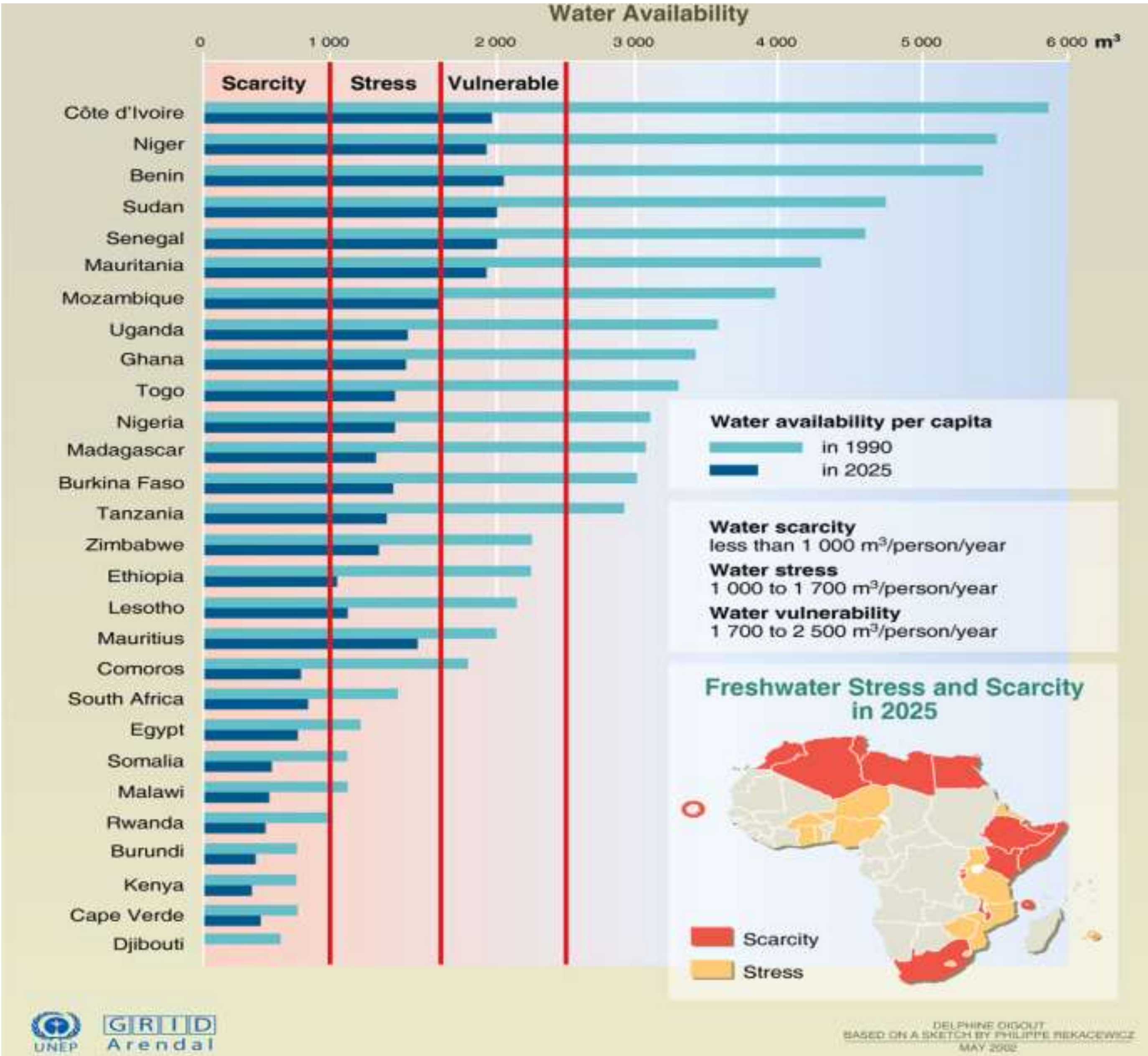


**Figure 1.** Per capita water availability in 1990 and 2025 in Africa (Bekele Shiferaw et al., 2014).

0.5 Mha by rain water harvesting (Awulachew et al., 2005).

According to the Ministry of Water, Irrigation and Electricity (MoWIE) set plan from 2002-2016 are 127,000 schemes identifications in the different regional states of Ethiopia. From this scheme identifications, 56% are by traditional schemes, 19% are small-modern scale schemes and 25% covered by medium to large modern scale schemes (Amede, 2014; Awulachew et al., 2005). Also from this plan is around 560 irrigation potential sites on the major 12 river basins. Similarly from this planned, around 80% are from the arid and semi-arid land regions of Ethiopia. However, the plan set for development of all irrigation schemes are 1.85 Mha (35% of the total irrigation potential), which is planned to be achieved by the end of the five years GTP of 2015 of which around 46.11% potential are SSIS. 2.2 million farmers benefiting from these at household level, of which around 20% are female headed households. Actually irrigated area/schemes has not been estimated, but in this review indicate that still used 5 to 10% of 5.3 Mha of irrigated potential area (Garbero and Songsermsawas, 2016; Beyan and Jema, 2014; Dereje Mengistie, 2016). These indicate that, the existing irrigation development in

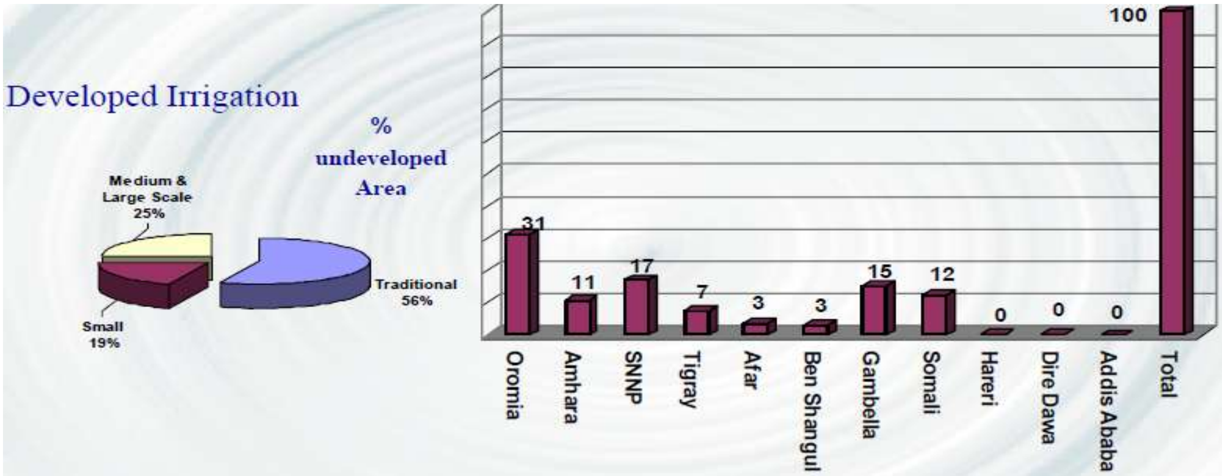


**Figure 2.** Proportion of undeveloped irrigation potential by region (%).

Ethiopia, as compared to the resources potential of the country, it is not significant and the irrigation sub-sector is not contributing its share accordingly (Gebremariam and Ghosal, 2016; Beyan and Jema, 2014). Ethiopia has set itself an ambitious task to achieve an irrigation target of 1.8 millionha for irrigation development (Gebremariam and Ghosal, 2016; Belay and Bewket, 2013).

In the region-wise, about 39% of the irrigated area is in Oromia in central Ethiopia, followed by 24% in Amhara in the north, 15% in Afar in the northeast and 12% in south nation nationalities and peoples regional (SNNPR), while the remaining 10% is in the other regions as shown in Figure 2 (Awulachew et al., 2005). Most this irrigated land is supplied from surface water. Different scenarios have been developed to explore a number of issues, such as the expansion of SSWHT and irrigated agriculture, massive increases in food production from rain-fed lands, water productivity trends and public acceptance of genetically modified crops. Opinions differ among the experts as to some of the above issues. However, there is broad consensus that irrigation can contribute substantially to increasing food production. Today, most of the world's food production comes from cultivated area. Over 86% of undeveloped irrigation potential in 5 main regions showing large investment opportunities (Hagos et al., 2010).

## Definition of small-scale water harvesting technologies (SSWHT)

SSWHT is a simple and low cost water supply technologies that involves the capturing, storing and convey of rainwater (in different structures or in the soil) from roof, runoff and ground catchments for domestic, agricultural, industrial and environmental purposes immediately or at a later time (Yosef and Asmamaw, 2015; Mume, 2014). SSWHT such as village ponds, sand dams and tanks have played an important role in rural life, particularly in the agricultural practices in different parts of the world including Ethiopia. Rainwater harvesting tanks: smallholder farmers are provided support to enable them to construct rainwater harvesting tanks on their land which enables them to collect and store water throughout the silt or sediment traps. If properly sited, these ponds can (i) reduce risk by supplementing rainfall in the main monsoon cropping season; or (ii) irrigate a smaller area of winter dry season crops (Titus Masila and Udoto, 2015).

## Definitions of small-scale irrigation scheme (SSIS)

Irrigation is categorized as small-scale, medium and large-scale depending on the area irrigated, scale of operation and type of control or management. But the criteria for this category may vary from country to country. For example, in India the irrigation scheme of 10000 ha is classified as small while in Ghana the largest irrigation scheme is 300 ha. A single definition for 'SSIS' is not easy to derive or is globally applicable. In terms of command area, in Ethiopia, SSIS are generally considered to command areas of about 200 ha or less (Gebremariam and Ghosal, 2016; Desta Dawit, 2015). A SSIS is defined as a scheme that serves a command area less than 25 ha in the hills and less than 200 ha in the Tarai (Bekele and Ayana, 2011). SSIS is irrigation that usually practiced on small plots where small farmers have the majority controlling influence, using a level of technologies which they can operate and maintain effectively (Desta Dawit, 2015). Hence, SSIS is, therefore, farmer-managed that is farmers involved in the design process and, in specific, with decisions about boundaries, the layout of the canals, and the position of

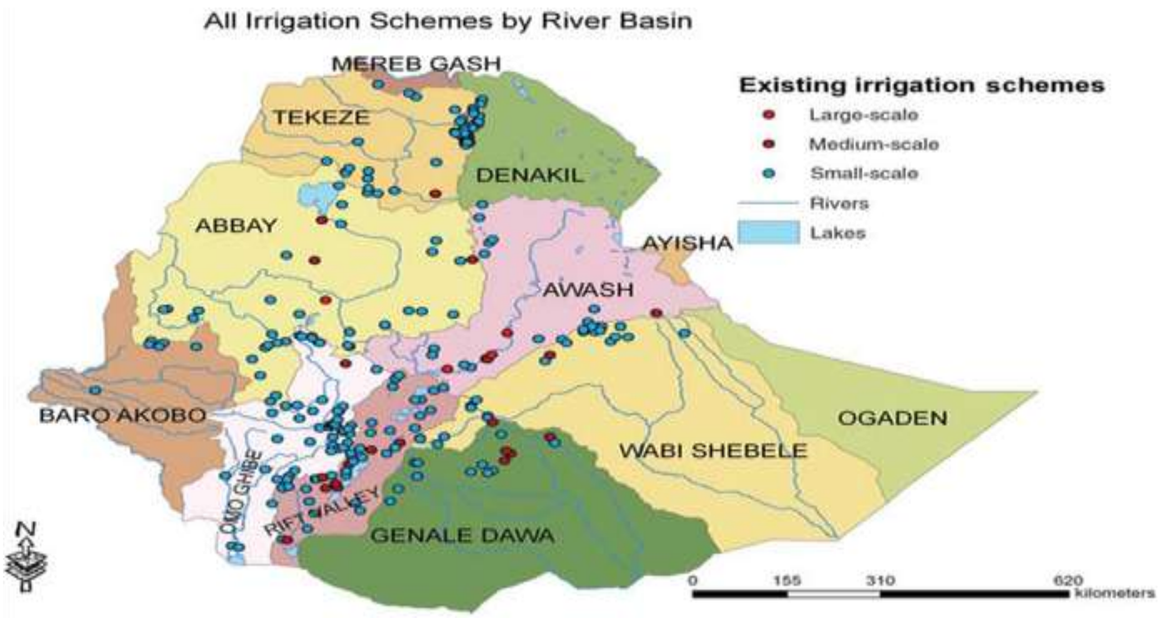


**Figure 3.** Existing irrigation schemes in various river basins in Ethiopia.

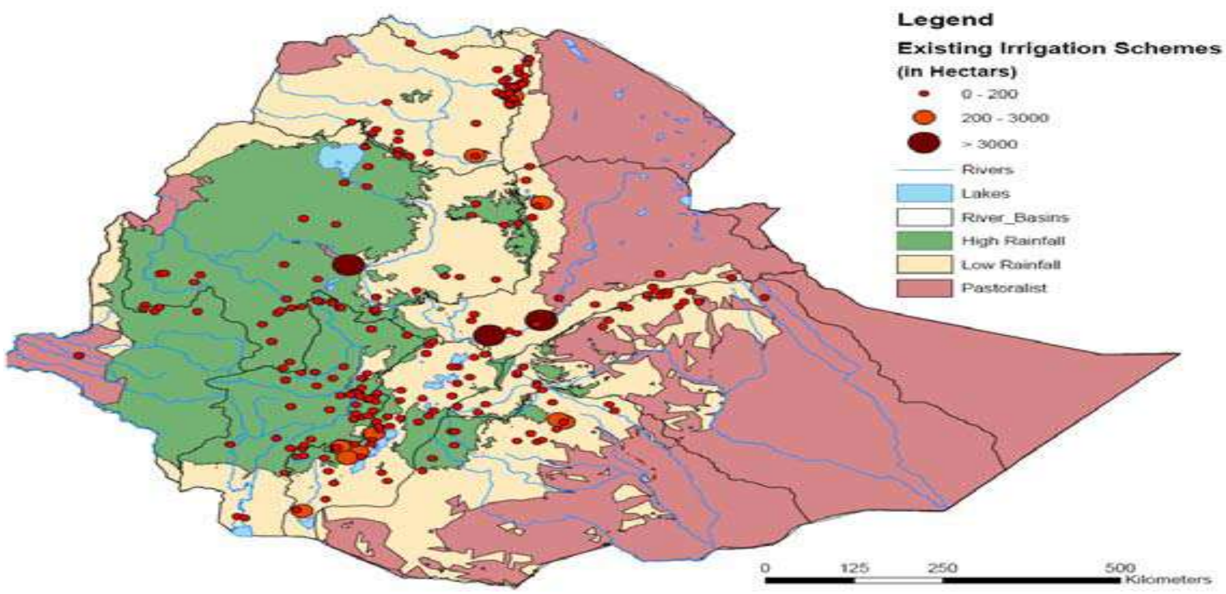


**Figure 4.** Existing irrigation schemes in various river basins with regional rainfall in Ethiopia.

outlets and bridges. As a result, the preference for SSIS is based on the perceived easy adaptability of the systems to local environmental and socioeconomic conditions is shown in Figures 3 and 4 (Gebremariam and Ghosal, 2016).

There are two major classifications of SSIS, the modern scheme and the traditional scheme. The development of modern SSIS started since the mid-1980s. They have relatively permanent structure and improved water control system, and are mostly constructed by either the government or NGOs. The traditional ones are constructed by the local community, commonly diverting water from rivers using local materials. There is always a need to reconstruct every year after the end of the rainy season, but it is sustainable in the water management system for a longer period of time. Both traditional and modern SSIS are farmer-managed irrigation systems with their own local

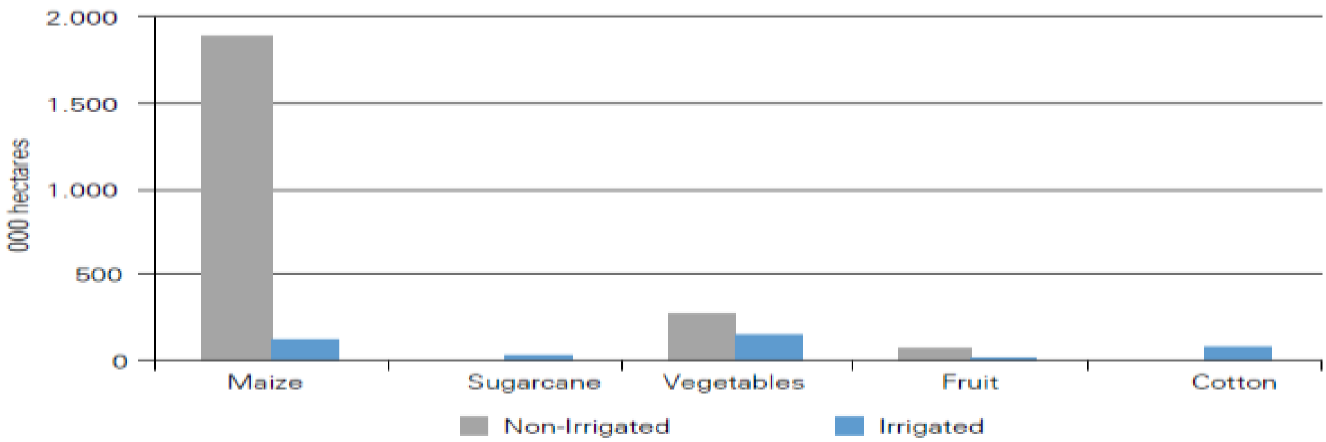


**Figure 5.** Area estimates for the main irrigated crops in Ethiopia – 2012 (FAO and IFC, 2015).

leadership of water users' associations or irrigation cooperatives, assisted by public extension systems (Awulachew et al., 2005). Traditional water management institutions have established with their own initiatives based on their local experience and indigenous knowledge, and perform better than modern water management institutions, such as the Water Users' Association (WUA) and irrigation users' cooperatives (IUCs) which were established through government initiatives (Hagos et al., 2010). The SSIS in Ethiopia are understood to include traditional small-scale schemes up to 100 ha and modern communal schemes up to 200 ha (Hagos et al., 2010). The canals are usually earthen and the schemes are managed by the community. A SSIS is, therefore, farmer-managed: farmers must be involved in the design process and, in particular, with decisions about boundaries, the layout of the canals, and the position of outlets and bridges. These SSIS which usually use diversion weirs made from local material and needs annual maintenance (Gebremeskel Haile and Kebede Kasa, 2015). Although some SSIS serve an individual farm household, most serve a group of farmers, typically comprising between 5 and 50 households. Examples of SSIS include household-based RWH, hand-dug wells, shallow wells, flooding (spate), individual household-based river diversions and other traditional methods. Many development organizations believe that small-scale irrigation schemes are an effective way to increase food production (Mesfin and Nahusenay Teamer Gebrehiwot, 2015; Fanadzo, 2012; Hintsa Libseka and Welde, 2015).

## BENEFITS FROM SMALL-SCALE RAINWATER HARVESTING AND PARTICIPATORY SMALL-SCALE IRRIGATION SCHEMES

Comparative yields analysis by crop type could not be done because of lack of uniformity in the use of inputs and inadequate documented in the Ethiopia. However, virtually all food crops (97%) in Ethiopia come from rainfed agriculture, with the irrigation subsector accounting for only about 3% of the food crops (FAO and IFC, 2015). The major cereals (maize, sorghum, wheat, and barley) dominate crops by volume and value, followed by industrial crops such as sugarcane, vegetable, cotton, roots (potato and sweet potato) and fruits are mostly irrigated is shown in Figures 5 to 8. These crops are supported by traditional water harvesting practices, particularly in central-north, eastern, and southeastern areas of the country. The proportion of traditionally irrigated land (almost half of the total irrigated area) and the number of farmers involved indicate the significant economic and social role of traditional irrigation for rural society. Urban and peri-urban irrigation are not significant in terms of area coverage and production, but the traditional irrigation practiced around Addis Ababa plays an important role in supplying vegetables to the Addis Ababa market. The use of irrigation technology, although currently not widespread, can reduce risk and improve production (FAO and IFC, 2015).

In Figure 8, the inner (yellow) circles represent the estimated current irrigated area of crops in Ethiopia. The outer circles are proportionate to the relative total area sown with these crops: maize, sorghum, and wheat are the dominant crops. About 37% of all vegetable production is irrigated with flood irrigation, and 100% of sugar and cotton production is irrigated (FAO and IFC, 2015).

When comparing between irrigators and non-irrigators, irrigators have small household size, higher level of education, large livestock holding size, and better quality (fertility) cultivable land. The irrigators had also better access to extension and credit services (Figure 9). In conclusion, irrigators are better in terms of food security status and other welfare indicators (Dereje Bacha et al., 2011).

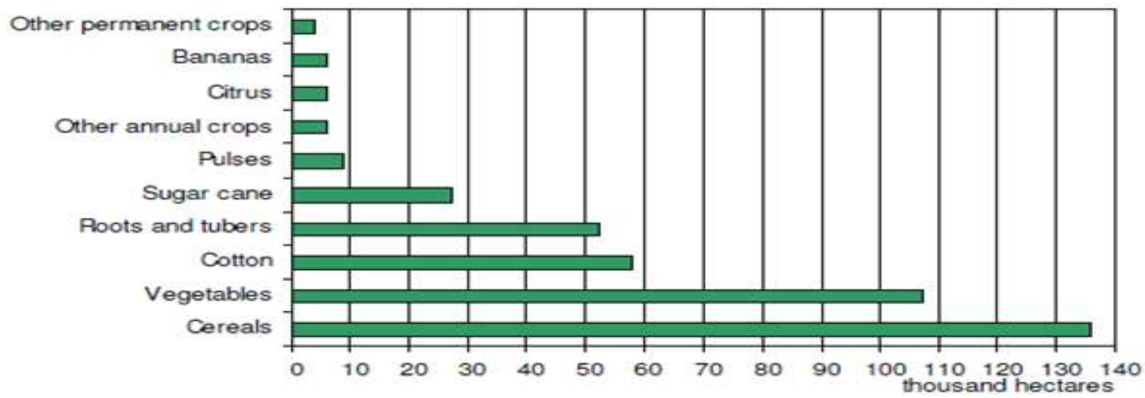


**Figure 6.** Irrigated crops in ha in 2016 in Ethiopia.

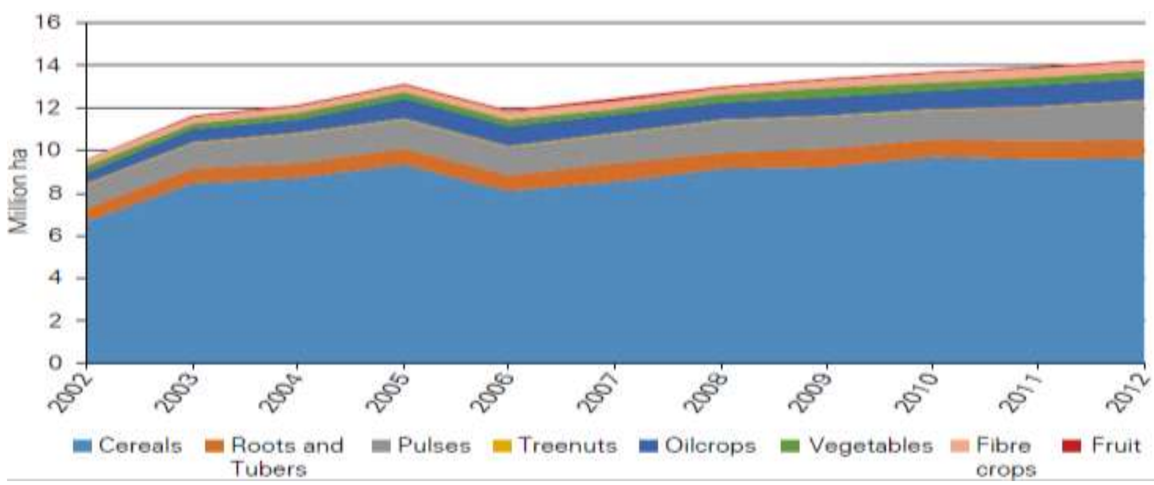


**Figure 7.** Harvested area by crop group in Ethiopia, 2002–2012 (FAO and IFC, 2015).

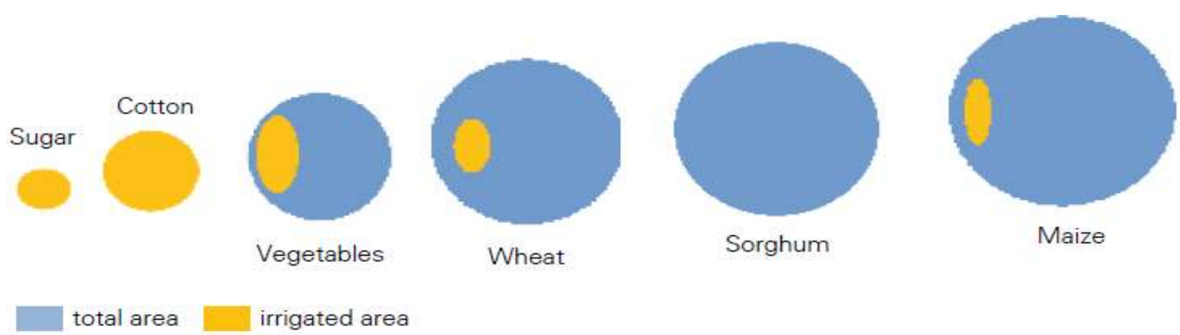


**Figure 8.** Estimates of the relative size of irrigated area by crop in Ethiopia (FAO and IFC, 2015).

## CONSTRAINTS AND FUTURE OPPORTUNITIES OF PSSIS AND SSWHT DEVELOPMENT IN THE ETHIOPIA

### Constraints of SSWHT and SSIS in the Ethiopia

Inefficient SSWHT and PSSIS system management has become one of the bottlenecks in the implementation of irrigation development in the Ethiopia (Gebremariam and Ghosal, 2016). Insufficient external/internal support from relevant stakeholders and low level of efficiency of the irrigation users' cooperative (IUC) were the major reasons for the poor performance of the IUC, which is unable to undertake its day to day activities (Abraham

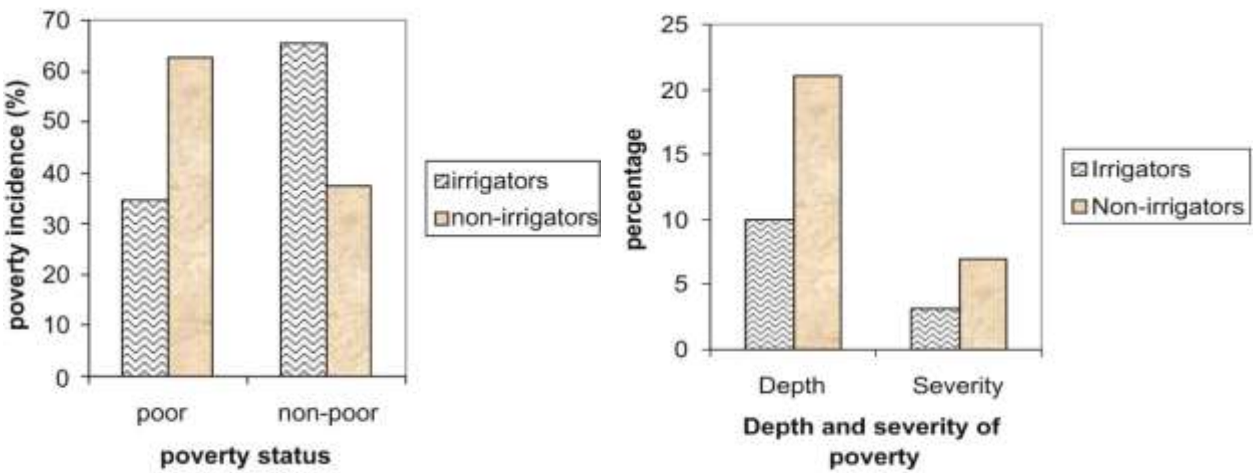


**Figure 9.** Household food security status differentiated among irrigators and non-irrigators (Bekele and Ayana, 2011; Gebremeskel Teklay, 2014).

Gebrehiwot Yihdego and Addis Adera, 2015). Irrigation management transfer as a policy instrument has started to be practiced in the water scarce regions of the Ethiopia to make SSIS management effective through the establishment of a locally created farmers' organization, specifically establishing an irrigation users' cooperatives (IUCs). However, the challenges faced by the IUCs for the management of SSIS have not been studied well (Abraham et al., 2015; Gardachew and Hanaraj (2013).

There is no effective enforcement of the rules and regulations of the IUC due to inefficient service delivery of the kebeles social courts, especially in addressing cases and forwarding timely decision for non-member offenders (Abraham et al., 2015). The kebeles administration would also not put in effect the decision made by the social court. Since most members of the kebeles administration are from different village that does not have irrigable land within the command area, they are not interested in being involved in the irrigation activities (Gebremariam and Ghosal, 2016).

The existing executive committee of the IUC is also not committed in identifying offenders and bringing them to social courts to get appropriate penalties against their illegal activities. One basic problem with regard to enforcement of rules and regulation in the bylaws is that, it could not be acceptable to a court if not endorsed by all water users (Gardachew and Hanaraj, 2013). The existence of two categories of farmers that is being member and nonmember to the cooperative in a scheme will have a problem to enforce decision to all water users which is only made by members of the cooperative. This situation indicates that there is no difference in benefit between members and non-members of the IUC, which discourage members to actively participate in irrigation management activities and could be a cause for non-membership of the IUC (Gebremariam and Ghosal, 2016).

According to Gebremariam and Ghosal (2016), Amede (2014) and Abraham et al. (2015), although these challenges can be explained as technical constraints and knowledge gaps are identified (1) inadequate awareness of irrigation water management as in irrigation scheduling techniques, water saving irrigation technologies, water measurement techniques, operation and maintenance of irrigation facilities, (2) Inadequate knowledge on improved and diversified irrigation agronomic practices, (3) Shortage of basic technical knowledge on irrigation pumps, drip irrigation system, sprinkler irrigations, surface and spate irrigation methods, (4) Loss of water through seepage: this is caused by non-durability of the physical structure of river diversion, (5) Scheme based approach rather than area/catchments based approach for the development of small-scale rain water harvesting and small scale irrigation schemes, (6) inadequate baseline data and information on the development of water resources, (7) lack of experience in design, construction and supervision of quality irrigation projects, (8) low productivity of existing irrigation schemes, (9) inadequate community involvement and consultation in scheme planning, construction and implementation of irrigation development, (10) Poor economic background of users for irrigation infrastructure development, to access irrigation technologies and agricultural inputs, where the price increment is not affordable to farmers (Gebremariam and Ghosal, 2016).

## Future opportunities for promoting of SSWHT and PSSIS in the Ethiopia

According to (Gebremariam and Ghosal, 2016) when farmers grow more food and earn more income, they are better able to feed their families, send their children to school, provide for their families health, and invest in their farms in a sustainable way. Helping farmers improve their yields requires a comprehensive approach that includes the use of seeds that are more resistant to disease, drought and flooding; information from trusted local sources about more productive farming techniques and technologies. Although there is sell more crops (greater access to markets; and government policies that serve the interests of farming families), is the most effective way to reduce hunger and poverty over the long term. This makes their communities economically stronger and more stable. Addressing this gap can help food security and livelihood of rural households become more productive and reduce malnutrition within poor families (Hintsa Libseka and Welde, 2015).

According to Amede (2014) and Hintsa Libseka and Welde (2015), although these future opportunities can be explained as technical freedoms and knowledge opportunity are identified (1) High water potential, (2) High commitment of the Ethiopia government, donors and NGOs to support irrigation management and development activity, (3) Opportunity for implementing multiple use water systems (MUS), with regions coordinating sub-activities. Effective utilization of scheme infrastructure through diversification of uses to meet various needs for water such as domestic, irrigation, livestock and hygiene is the most important, (4) Opportunities for improving knowledge of policy makers, planners, designers. (5) Contractors and development agencies through education, training, dialogues and participation, (6) Opportunities for more gender-equitable investments, targeting poor women, through for example MUS and micro irrigation.

## CONCLUSIONS AND FUTURE LINE OF WORK

Over the last few years experiences concerning the development of PSSIS and SSRWHT systems are often designed to maximize efficiencies and minimize labour and capital requirements. A number of scholars have disputed on the PSSIS and SSRWHT facilities play a crucial role in ensuring food security. Review shows that numerous problems in all PSSIS and SSRWHT. Government, donors and NGOs are investing in developing irrigation systems, especially on PSSIS and SSRWHT. Nowadays, the policies and strategies of Ethiopia strongly supports the irrigation developments especially the PSSIS and SSRWHT via the Water Sector Development Programs (WSDP) and Ethiopian Irrigation Development Plan (IDP). Still used 5 to 10% of 5.3 million hectares of irrigated potential area. Among various issues that affect sustainability in community based of PSSIS and SSRWHT, 'design of the irrigation scheme' is the major component that needs special consideration. Thus the challenges to continuous PSSIS and SSRWHT development indicators monitoring will be immense. In Ethiopia is a viable development strategy but attention needs to be paid to improving the technology available to farmers under both rainfed and irrigated production. The major bottlenecks for sustainability of PSSIS and SSRWHT project are profitability, water management and infrastructure maintenance. Therefore, need urgent intervention on the PSSIS and SSRWHT development strategy all stakeholders is highly recommended.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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