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Guidelines for sustainable irrigation system design and management in sub-Saharan Africa

Mathias Fru Fonteh

Department of Agricultural Engineering, Faculty of Agriculture, University of Dschang, Cameroon.

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Despite the fact that the economies of most countries in sub-Saharan Africa (SSA) are dominated by the agriculture sector, the productivity of the sector is still very low. One of the factors responsible for this is the fact that agriculture in SSA is mainly rain fed despite the abundant water resources in the region. Many attempts have been made in SSA to expand irrigation but most of these efforts have not been successful. The goal of this study was therefore to learn from the few irrigation success stories in SSA, and propose guidelines for sustainable irrigation development. This will thereby contribute to helping farmers adapt better to climate change, increase productivity, ensure food security and consequently eliminate hunger and poverty. The major findings of the study are that irrigation designs should be participatory, tuned to the farmers' objectives, seek to maximize water use efficiency with priority given to small-scale irrigation systems, and ensure that water supply is reliable. Furthermore, designs should provide opportunities for farmers to grow a variety of crops to ensure both food security and income generation. In addition, farmers should make a significant contribution in the implementation of irrigation projects as well as have significant management responsibility for the completed system which will increase their sense of ownership and commitment. Finally, it is crucial to create an enabling environment for irrigation development by: facilitating access of farmers to water, land, credits, other agricultural inputs, and markets; building capacity of all key stakeholders in irrigation development and facilitating the creation of functional water users associations.

Key words: Successful irrigation development, design considerations, management constraints.

INTRODUCTION

The agricultural sector is very important in sub Saharan Africa (SSA) and the economies of most countries in the region are dominated by this sector. According to UNCTAD (2016), the sector employed about 36.7% of the total workforce in SSA in 2015. Furthermore, in many countries, over 50% of the workforce is engaged in agriculture with a proportion of over 90% in some countries like Burundi. About 17% of the gross domestic product (GDP) in the region is generated by the agricultural sector (The World Bank, 2016). In some countries, agriculture generates up to 50% of the GDP, contributes over 80% of trade in value and more than 50% of raw materials to industries (FAO and UNIDO, 2008).

Despite this importance, the productivity of the sector is

E-mail: matfonteh@yahoo.com. Tel: +237 6 77 74 08 63.

low as compared to that of other developing regions in the world. For example, yields of cereals, a staple in many parts of SSA is only about 36% of that in Latin America and Caribbean and about 48% of the yields in South Asia (The World Bank, 2016). One of the factors responsible for the low productivity in SSA is the fact that agriculture is mainly rain fed. The World Bank (2016) estimates that in 2014, only about 3% of the internal renewable fresh water resources in SSA was withdrawn for all purposes. This suggests there is abundant water resources but despite this, in 2012 only about 3% of the arable land was irrigated in SSA (FAO, 2016a). This is very low as compared to Asia where the proportion of arable land that is irrigated varies from 33 to 42% and the global average proportion of arable land irrigated of 21% (FAO, 2016a). The sub-region in SSA with the lowest percentage of arable land irrigated is central Africa with 0.6%, while the highest is southern Africa with about 7%. This indicates that there is an enormous irrigation potential in SSA. FAO (2016b) has concluded that the greatest potential for expanding irrigated agriculture in the world, considering both land and water resources, is in the sub-Saharan Africa region, where only one fifth of the potential irrigable area has been developed.

Irrigated croplands have much higher yields than rain fed croplands. It is estimated that irrigated agriculture represents 20% of the total cultivated land in the world, but contributes 40% of the total food produced worldwide (FAO, 2016b). Irrigation is therefore a key input in ensuring food security in the world. Siebert and Döll (2010) estimated that global cereal production would decrease by 20% without irrigation, while Neumann et al. (2011) concluded that climate change and population growth will further enhance the role of irrigation in the future. As such, greater use of irrigation in SSA, will increase food production, help farmers adapt to climate change, play an important role in farmers transitioning from subsistence to commercial farming and ensure food security as well as reduce poverty (Tefera and Cho, 2017; Eneyew et al., 2014). FAO (2016b) documented that irrigation in conjunction with high-yielding varieties; inputs such as fertilizers and pesticides; and the use of agricultural machinery played a significant role in the green revolution in Asia. This is because, irrigation leads to the intensification of agriculture and can result to year round production. Without irrigation, farmers engaged in market gardening can grow only one crop a year whereas with irrigation, they can grow two or three crops a year.

Over the years, many attempts have been made in SSA to expand irrigation (Kadigi et al., 2012; Namara et al., 2011; Inocencio et al., 2007; Drechsel et al., 2006; Morardet et al., 2005; Fonteh, 1998). The fact that the extent of irrigation is still very small in the region indicates that most of these efforts have not been successful, leading to the perception that irrigation systems in SSA have been a failure. Hence, there is reluctance by investors to expand irrigated areas. The reality however is that there has been success stories as well as failures and that we can learn from the past to develop a more sustainable future.

The goal of this study was therefore to develop guidelines for sustainable irrigation development in SSA that can contribute to expanding irrigation, increase productivity of farmers to ensure food security. This can make a significant contribution towards the attainment of the first five sustainable development goals (UNDP, 2017) related to poverty, hunger, health, education and gender equality. Specifically, the study sought to identify critical design and management issues of successful irrigation projects in SSA, identify constraints to irrigation development in the region resulting in poor performance; and finally to recommend a way forward that can ensure that irrigation development in SSA is sustainable.

The methodology used in this paper was based on a systematic and critical review of published and unpublished literature on irrigation development in sub-Saharan Africa in particular and in other developing regions of the world in general.

KEY DESIGN CONSIDERATIONS FOR SUCCESSFUL IRRIGATION DEVELOPMENT

The following issues which have a major bearing on the success of an irrigation system will be discussed in turn. These are: the adoptability of the system; the economic feasibility; the performance and management of the system, the sustainability and finally the enabling environment.

Adoptability of the system

Irrigation is a socio-technical system. The technical aspects of irrigation are easier to solve but the social aspects are more complex and difficult. For example, it is much easier to design and construct an irrigation system than ensuring it functions well. Issues to resolve in the social aspects include, efficient distribution of water and with equity, maintenance of the system and managing conflicts. The social dimensions of irrigation are as important as the technical dimensions but they are often not adequately taken into consideration resulting in the non-adoption of some irrigation systems.

Three factors influence the adoption of water management technologies (Fonteh and Ajaga, 1998). Firstly, the cost from the point of view of affordability by the users not only to acquire, but also to operate and maintain the technology. Secondly, for a technology to be adoptable and sustainable, it should fit neatly into the social structure of the users and the community. As such designers should tune the objectives of the system to that of the farmers and not the reverse (Ubels and Horst, 1993). This approach results in designs that are flexible.

Thirdly, the nature of the technology. There are many aspects to this. Is it technically appropriate, that is, doing what is supposed to be done. According to Rogers (1962), the factors of the technology itself that influence its adoption are; its divisibility, its availability to potential users, relative advantage over other technologies, compatibility with existing value system and the complexity of the technology.

To ensure adoption of an irrigation system, it is critical to maximize the participation of farmers in all stages in the design. This is important in the selection of the crop to be grown, type of system to use, layout of plots, tuning the design to their social and cultural environment, designing so that operation/maintenance suits their capacity, etc. Participatory design also ensures that designs are based on informed decision, making use of valuable local information especially as many designs in SSA are often carried out with limited reliable official data.

Many studies have highlighted the need for participatory irrigation design as the key to ensuring adoptability. For example, a study by Morardet et al. (2005) concluded that if designs do not take into account actual on-the-ground operational and management capabilities of farmers, this can seriously affect the performance of irrigation systems. Merrett (2002) on his part stated that the most essential stakeholder in an irrigation system is the farmer, who, if not properly integrated in the system development, may not feel obliged to play his/her role effectively, thus jeopardizing the sustainability to the system.

Farmers, as a possible source of system design input, are still too often ignored by engineers, and as a result systems are often inappropriately designed. Giordano et al. (2012) reported that the designs that will have the best impacts are those taken into account, at the planning stage, the livelihood contexts in which smallholder farmers operate.

Understanding farmers' needs will ensure that actions to support them are beneficial. This requires involving farmers in the design process which usually results in flexible irrigation systems. Examples of flexible systems are: the use of individual low cost water lifting devices to pump water from shallow ground water or from rivers. The pump can be moved from one field to another to permit multi farm use. Another approach could be to pump water into storage tanks located in an irrigation area to enable farmers carry water from there to irrigate when they wish to irrigate. Flexible systems may also entail zoning, with farmers having plots in different zones with different soil types to facilitate growing a variety of crops.

Economic feasibility

This depends on the cost of the system and the returns on the investments.

Cost of the system

The cost is determined mainly by the scale of the irrigation and the type of irrigation system selected.

Scale of irrigation: Project size is the most important factor which determines unit investment cost of irrigation projects (Inocencio et al., 2007). Relatively large investment projects irrigating large areas have lower development costs/ha because they achieve significant economies of scale. Most of the irrigation systems in SSA can be grouped under two types; large-scale and small-scale. According to Carter (1989), small-scale irrigation (SSI) refers to irrigation of small plots in which private farmers have the controlling interests and using technology which they can effectively operate and maintain. The farm sizes usually do not exceed 0.2 ha. Large-scale irrigation usually refers to formal sector irrigation where the development and management is carried out in a structurally formal way, usually by the state or an agri-business concern. Large-scale irrigation systems therefore logically result in large investment projects which usually have lower development costs per unit area.

However, according to Inocencio et al. (2007), small-scale irrigation schemes offer significant performance advantages over large-scale systems within irrigation investment projects. A study by Giordano et al. (2012) concluded that smallholder farmers in sub-Saharan Africa and South Asia are increasingly using SSI to cultivate their land. Individually owned and operated irrigation technologies improve yields, reduce risks associated with climate variability and increase incomes. There is great potential for many more farmers to benefit from small-scale irrigation. In addition, in many African countries, water management by smallholders is already more important for irrigation than the public irrigation sector, in terms of the number of farmers involved, the area covered and the value of production. For example, in Ghana, private irrigation by smallholders employs 45 times more individuals and covers 25 times more land than public irrigation schemes (Namara et al., 2011). The increasing importance of SSI systems is because they are more flexible, can be more easily tuned to the farmer's context; are more adoptable and hence sustainable. SSI is intricately linked with poverty and gender issues. This is because most of the irrigation activities are carried out by women and disadvantaged groups. SSI is therefore pro poor and contributes to alleviating poverty and empowering women. In order to reduce the unit cost of irrigation development in SSA, and also have systems which perform very well, small-scale irrigation systems should be developed within the context of large-scale investment projects which have significant economies of scale and are cheaper. A large investment project comprising many small-scale systems will be able to justify recruiting qualified personnel (e.g. irrigation engineers and project managers), mobilizing the appropriate equipment for construction, and can invest sufficiently in the software components (good planning, design, project management, supervision, effective training, capacity building and institutional development among future users and managers).

Both small and large scale irrigation systems are required in SSA. According to Fonteh (1998), the key to their success is whether they are privately or publicly managed. This is because large scale systems which were performing poorly when they were state managed, started performing very well when they were privatized. Youa et al. (2011) also concluded that there is significant profitable irrigation potential for both small-scale and large-scale systems. However, if attainment of the first five SDG is an objective, then priority should be given to pro-poor SSI.

Therefore, to ensure sustainability and minimize development costs, large irrigation projects supporting many small scale irrigation systems should be designed and developed if there is demand and access to markets.

Types of irrigation system: There are two main types of irrigation systems in the world. These are surface irrigation (border, basin and furrow) and pressurized irrigation comprising sprinkler and drip irrigation. There is no universally technically "best" irrigation method for all situations (Burt et al., 2000). The selection of a technically appropriate method for a given context will depend upon such variables as: the soil type (infiltration rates, variability of soils and the available water content), the topography, the crop to be grown, climate conditions, local traditions and skills, the available water supply (quality, quantity and temporal distribution characteristics), and the support infrastructure for a selected technology.

In terms of worldwide use, pressurized irrigation accounts for about 14% of the total irrigated area (FAO, 2016b). This implies that surface irrigation systems account for about 85% of the total irrigated area. This domination of surface irrigation is partly due to the fact that when conditions permit and with abundant water resources, gravity operated surface methods are cheaper to construct if the construction of dams is not required. In addition, they are cheaper to maintain and operate. When surface methods are not suitable because of topographic and soil conditions, gravity operated pressurized systems are still desirable because the operation costs will be much lower. For example, in the Western Highlands of Cameroon, small scale gravity operated sprinkler systems have been use for many years, are very common and are sustainable (Ayangma, 1999; Lekeufack, 1998; Ngatchou, 1998;).

Inocencio et al. (2007) found that unit costs are significantly higher for river diversion systems with major storage capacity, and significantly lower for drainage/flood control systems as compared to simple river-diversion systems. In addition, the unit cost of irrigation projects implemented as part of multi-sectoral projects is lower than stand-alone irrigation projects.

The system selection process can be complex because there are many interrelated factors affecting the choice of methods which affects the cost. As such, irrigation systems should be designed by qualified irrigation engineers to ensure that they operate as expected.

Crops to be grown

The feasibility/performance of an irrigation system greatly depends on the crops to be grown, which affects the return on investments. Expensive irrigation projects can be economically feasible if they are used to grow high value crops like fruits and vegetables. An analysis of irrigation systems in 50 different countries in the world suggests that systems designed for staple cereals, tend to have higher unit costs and lower performance (a partial exception is rice in some cases) than systems designed for such crops as fruit trees, vegetables and fodder (Inocencio et al., 2007). This is because the demand for irrigation infrastructure such as dams, reservoirs, sluices and canals, is greater for traditional staple crops than for non-cereal crops, which require much lighter infrastructure. Further, the price of cereals has been declining sharply since the mid-1980s, resulting in worsening profitability relative to crops such as fruits and vegetables, the demand for which has been increasing as economies have developed.

Since irrigation leads to intensification of agriculture with possibility of year round production; for irrigation to be sustainable, there should be access to reliable or dependable markets for agricultural products with guaranteed prices. This can be a major constraint, which, if overcome, may encourage farmers to intensify agricultural production through irrigation. The irrigation of high value market gardening crops is therefore very attractive especially in peri-urban areas due to the easy access to markets. Farmer managed surface and sprinkler irrigation systems have been very successful in the Western Highlands of Cameroon because farmers grow high value vegetables during the dry season as well as early season maize (Fonteh, 1998). In order to ensure both food security and income generation, irrigation systems should provide opportunities for farmers to grow a variety of crops on different soil types to minimize risk. Income generation crops should preferably be high value market gardening crops. This will provide the flexibility and assurance which farmers need.

Performance and management of the system

Mode of operation and management of the irrigation system

The performance of an irrigation system has been observed to be greatly affected by the mode of operation and management. Is the system managed by farmers themselves; by the state or by both the state and farmers? Inocencio et al. *(*2007) observed that systems in which operation and maintenance (O&M) is carried out by farmers performed best; followed by systems in which O&M was shared by government irrigation agencies and farmers through water users associations (WUAs). Systems where O&M was carried out only by government agencies had the least performance.

If farmers who are the most important stakeholders are to manage an irrigation system, then their involvement needs to be maximized so that designs are tuned to their social and cultural environment; and to suit their capacity to operate and maintain the system. In fact Kadigi et al. (2012) went as far as recommending that new irrigation systems should only be initiated in response to the demand from farmers because this increases the chances of local management and maintenance of the system. Stakeholder participation in the planning and decision making processes of irrigation systems is an effective way of developing systems that are most likely going to be sustainable. This should be initiated during the planning stage in order to win the support of various stakeholders.

Maximizing farmers' involvement in the development of their systems (consistent with their capacity) combined with farmers taking significant management responsibility for the completed system usually results in lower O&M costs and higher performance.

Reliability of water supply

For an irrigation system to be sustainable, there is need for a reliable water supply. When surface water supplies are used; to ensure a reliable water supply, adequate storage facilities are often needed which increases the cost of irrigation projects. The conjunctive use of surface water with limited storage facilities and ground water ensures a reliable water supply without major increases in the cost of the project and improves the performance of the project. Foster et al. (2010) defined conjunctive use as a situation where: both groundwater and surface water are developed to supply a given irrigation canal-command although not necessarily using both sources continuously over time nor providing each individual water user from both sources. Groundwater pumping for irrigation used in conjunction with surface water provides benefits that increase the water supply or mitigate undesirable fluctuations in the supply (Tsur, 1990) and also help to control shallow water table levels and consequent soil salinity.

A study by Inocencio et al. (2007) revealed that projects which adopted conjunctive use of surface and ground water performed better than otherwise. As such, wherever conditions are favorable, the design of irrigation schemes should provide for conjunctive use of surface water and groundwater to ensure the reliability of water supply.

Organization of farmers

Irrigation of farmer-managed systems requires an elaborate network of canals, sometimes passing through farmers' fields. There is therefore a need to manage the water and the system collectively and this requires functional WUAs. According to Sagardoy et al. (1986), water users associations or specialized water management organizations can be defined as social organizations aimed at an appropriate use of water for irrigation purposes among the farmers of a community. The term "appropriate" is used here to designate a timely and equitable distribution of the water. The main functions of WUAs are: the operation of the irrigation and drainage systems, the maintenance of the systems, and the assessment and collection of water charges. The management of WUAs vary depending on the scale of the irrigation. For example in Cameroon, they are either managed by farmers or there is mixed control between farmers and the state (Fonteh, 2011). Small-scale irrigation systems are usually managed mainly by farmers, while large-scale public owned surface irrigated systems usually have mixed control.

Irrigation system design should therefore include software components whose aim is to facilitate the creation of functional WUAs. This is because farmers are better able to: enforce their own rules relating to the collection of levies; maintain and repair infrastructure; ensure equitable distribution of water; and manage conflicts amongst themselves.

Contribution of farmers to project development

It has been observed that in general, rural development projects in which the primary stakeholders contribute in the implementation of the project perform better than otherwise. A study in Tanzania by Temba (2015) concluded that when farmers contribute towards the development of an irrigation system, the performance of the system is enhanced. It was also noted that the higher the contribution provided by farmers, the greater the performance of the irrigation system. The contribution could be in form of resource mobilization, material contribution, setting standards for monitoring the project success, collaborative partnership, consultation and information giving. This is because there is a greater sense of ownership and commitment to the project.

Sustainability

Sustainability concept, when viewed within the context of SSI development generally refers to the long-term ability

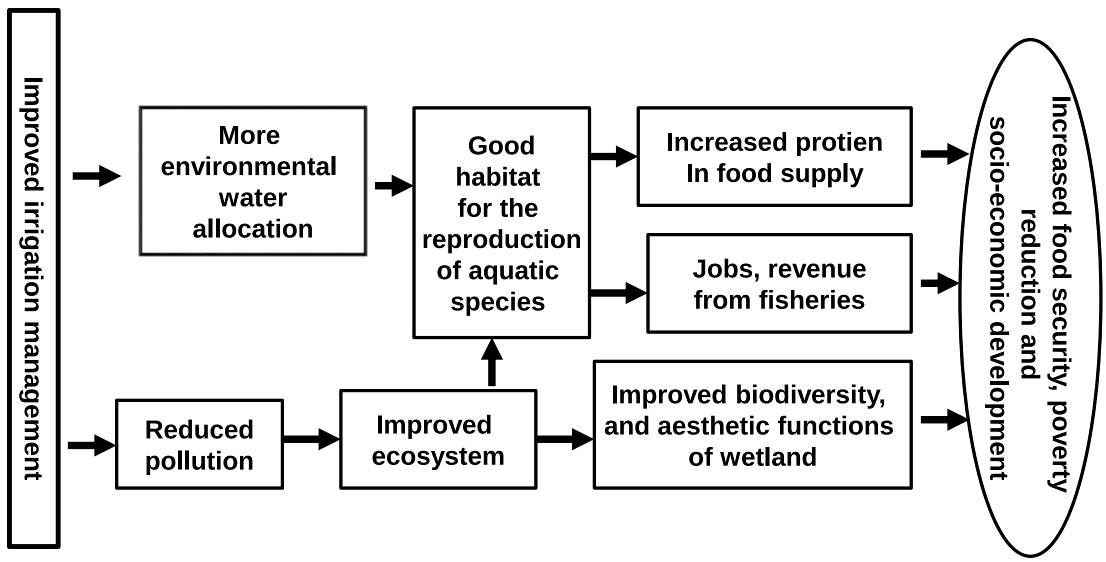

Figure 1. Effect of efficient irrigation water management on environmental stability, poverty reduction and socio-economic development.

of the beneficiaries to operate and maintain their schemes profitability with little or no external intervention other than the normal extension services (Giordano et al., 2012). In this light, there are two main aspects to SSI sustainability: socio-economic and environmental sustainability.

Socio-economic sustainability

This is often ensured when farmers adopt a new technology because it is appropriate from the technical, social and economic points of view. SSI systems have been noted to be more sustainable from the social and economic points of view. For example, in West Africa, the urban population is now greater than the rural population and informal irrigation systems in urban and peri-urban areas are therefore taking advantage of the growing urban markets and the inadequate refrigerated transportation and storage infrastructure, to complement rural agriculture in feeding the cities with fresh vegetables (Drechsel et al., 2006). As compared to farmers involved in traditional rain fed agriculture, farmers involved in peri-urban year-round irrigated farming can earn more than twice their income despite having much smaller farm sizes. This suggests that SSI systems are more socially and economically sustainable because they are appropriate.

According to Chancellor and Hide (1997), the design of an irrigation system is one of the main issues that affects socio-economic sustainability in smallholder schemes. The major issues that need special consideration are:

1. Installation,
2. Operation and maintenance costs,
3. Mechanisms to achieve efficient and equitable water allocation and
4. The control of water losses.

Environmental

Irrigation uses about 80% of all fresh water abstracted in SSA (FAO, 2016b). This can have negative impacts on the ecosystem by reducing the environmental water allocation. UN-Water (2006) estimated that the average application efficiency of irrigation in developing countries was 38% and that in addition, between 30 to 40% of water is lost in water distribution systems. Excessive withdrawals of water for irrigation can lead to: inadequate water available to meet environmental water requirements resulting in the degradation of the ecosystem; falling water tables which can lead to seawater intrusion in coastal areas, thereby polluting groundwater resources; pollution of both groundwater and surface water resources etc. Irrigation system design should therefore seek to maximize water use efficiency to ensure environmental stability which, as shown on Figure 1 also contributes to the alleviation of poverty and socio-economic development. If possible, designs should consider using new technologies which have better application efficiencies like sprinklers and low cost drip irrigation systems.

Enabling environment

Irrigation will only thrive if there is an enabling environment. For irrigation to be sustainable, it has to be carried out within the context of an overall agricultural development strategy, which itself must fit within a rural development and a broad national development strategy. These will ensure that farmers will have access to secure land and water; access to extension services, access to loans at preferential interest rates, availability of inputs like improved seeds, fertilizers and access to markets (roads, fair price for products and demand for products).

CONSTRAINTS TO SUSTAINABLE IRRIGATION DEVELOPMENT IN SSA

Below are some challenges confronting the development of irrigation in SSA. Measures have to be taken to overcome them before irrigation development can flourish in SSA in a sustainable manner. These constraints were identified based on findings from various parts of SSA.

1. The none-appropriateness of some systems mainly because farmers were not involved in the design and the design objectives were different from the farmers' objectives. As a result, systems do not function as well as intended because farmers operate them differently from what was planned.
2. Poorly designed and managed irrigation systems because of the limited number of local specialists in the domain resulting in systems being designed and constructed by amateurs. A study in Ghana by Namara et al. (2011) highlighted the need for competent irrigation engineers in the design of small-scale irrigation projects. The study revealed that inadequate planning and faulty design are sometimes the culprit behind the poor performance of irrigation systems. In addition, inadequate facilities and design problems are often major reasons behind inadequate distribution of water from a source to farmers' fields. Poor designs result in inefficient technologies which Ofosu et al. (2014) identified as a vital factor for successful irrigation development in SSA.
3. Inadequate capacity of farmers in irrigation management because irrigation is new in many communities and also due to poor extension services (Labassou, 2005; Tekeubeng, 1999; Ayangma, 1999; Lekeufack, 1998; Ngatchou, 1998). As such most farmers do not know when to irrigate and how much water to apply. A study by Tafesse (2003) concluded that limited knowledge in agricultural water management was one of the main constraints to irrigation development in Ethiopia, Ghana, Kenya, Tanzania and Zambia. This is consistent with the findings of Eneyew et al. (2014) in Ethiopia; and Fanadzo (2012) and Machethe et al. (2004) in the Republic of South Africa who identified inadequate capacity as an important determinant of poor irrigation system performance.
4. Poor organization of farmers. This is partly responsible for poor maintenance and repairs of irrigation infrastructure and equipment. For example in the Central African sub-region, there are very few veritable irrigation WUAs (FAO-SFC, 2009).
5. Absence of monitoring, evaluation and feedback systems. This leads to reduced management responsiveness and lack of data to improve the systems.
6. High cost of irrigation development. Inocencio et al. (2007) concluded that between the year 1965-2000, the average construction cost of irrigation systems in SSA was US$ 14,500/ha while in non-SSA countries, it was US$ 6,600/ha. However, an analysis of irrigation projects in SSA which are deemed successful indicated that these are not more expensive than in other regions of the world.
7. Poor enabling environment. This is manifested by the following: poor or non-existent extension services in irrigation due to inadequate financial and human resources; land tenure problems which makes farmers hesitant to invest in water management infrastructure; inadequate political will and commitment leading to insufficient investments in agriculture in general and irrigation in particular; poor access to credits and poor access of farmers to markets.

A number of studies have concluded that a poor enabling environment is one of the most serious challenges to developing irrigation in SSA and that the main issues are; insecure access to land and water, ineffective institutions and unfavorable policies (Ofosa et al., 2014, Fanadzo, 2012; Namara et al., 2011; Machethe et al., 2004).

CONCLUSION AND RECOMMENDATIONS

For sustainable irrigation development in SSA that can contribute to expanding irrigation and increase productivity of farmers to ensure food security, the following guidelines should be followed:

1. Irrigation design should be participatory with the objectives of the system tuned to satisfy the farmers and not the reverse. This will result in flexible designs to suit the socio-cultural environment of farmers and enhance adoptability.
2. The development of SSI systems should be given priority in order to ensure the sustainability of irrigations systems, promote food security and alleviate poverty in SSA. However, since large-scale investments cost less per unit area; in order to reduce the unit cost of developing SSI systems in SSA, they should be designed and developed within the framework of large-scale investment projects which have significant economies of scale and are therefore cheaper.
3. When conditions permit, gravity operated surface methods are cheaper to construct if the construction of dams is not required. In addition, they are cheaper to

maintain and operate. When surface methods are not suitable because of topographic and soil conditions, gravity operated pressurized systems could be used because their operation costs will be much lower. In addition, irrigation projects should be implemented as part of multi-sectoral projects instead of stand-alone projects to reduce the unit cost.

4. Irrigation systems should provide opportunities for farmers to grow a variety of crops on different soil types to minimize risk and ensure both food security and income generation preferably from high value market gardening crops.

5. Farmers should make significant contributions in the implementation of irrigation projects as well as have significant management responsibilities for the completed system. This increases the sense of ownership and commitment and enhances the performance of the system. This usually results in lower O&M costs and higher performance.

6. The design of irrigation systems should provide for conjunctive use of surface water and groundwater to ensure the reliability of water supply wherever conditions are favorable.

7. Irrigation systems should be designed to maximize water use efficiency and to ensure environmental stability which also contributes to the alleviation of poverty and socio-economic development. If possible, designs should consider using new technologies which have better water application efficiencies like sprinklers and low cost drip irrigation systems.

8. States should strive to create an enabling environment for irrigation development by: facilitating access of farmers to water, land, credits, other agricultural inputs, and markets; building the capacity of all key stakeholders in irrigation development and facilitating the creation of functional WUAs.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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