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SUSTAINABLE MICRO-IRRIGATION SYSTEMS FOR POVERTY ALLEVIATION IN THE SAHEL: A CASE FOR "MICRO" PUBLIC-PRIVATE PARTNERSHIPS?

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ABSTRACT
Irrigated agriculture in most parts of Sub-Saharan Africa has not been encouraging even with the threat of severe adverse effects of global food and financial crises and a scourge of the consequences of climate change. The situation in the West African Sahel is even more disturbing since it is at the fringe of the Sahara desert and past attempts at irrigation development have been very disappointing. The paper analyses information from an assessment of the extent of use and impacts of micro irrigation technologies in Burkina Faso, Mali, Niger and Senegal, and suggests a future direction for irrigation development in the West African Sahel. It argues for substantial investments by Governments, NGOs and the private sector in development of "low-cost" micro irrigation system. Drip irrigation in the form of the "African Market Garden" (AMG) is a technology that has the potential to drastically reduce mass poverty levels in the Sahel. It has been widely acclaimed by smallholder irrigators in the Sahel as being suitable for the arid environment and it has been shown to be profitable to the farmers. The cost of establishing a viable, effective, and sustainable smallholder drip irrigation system is however above the capabilities of small farmer groups. The suggestion is to institute modified public-private partnership (PPP) methodologies of funding and management of farmer-group drip irrigation systems to ensure, adequate funding and that, viable, sustainable and poverty alleviation systems are established in all parts of the Sahel and in similar areas in Sub-Saharan Africa.

I. INTRODUCTION

Globally, irrigated agriculture plays a very important role in food security and livelihood improvements, especially in Asian farming systems. It is however not so in most parts of Africa, especially West Africa (Dittoh, 1991), despite the known fact that climate change has resulted in reduction in precipitation and increased fluctuation of the weather pattern, with the attendant adverse effects on dryland rainfed agriculture (Kurukulasuriya and Mendelsohn, 2006; Ouedraogo et. al., 2006; Sene et. al., 2006; African Business, July 2008 p.24). In contrast to rainfed farming, precipitation has virtually no effect on the productivity and profitability of irrigated farms (Kurukulasuriya and Mendelsohn, 2006). It is, thus, obvious that the deleterious consequences of climate change on African rainfed agriculture would be far more than in irrigated farming systems, particularly in arid and semi-arid areas. The current African and world food crisis is partly being blamed on climate change and lack of needed water management infrastructure (Morris, 2003; WFP, 2010; Oxfam, 2010). Climate change and its resultant uncertainties in rainfed agriculture makes investments in water storage increasingly critical (World Bank, 2007).

Sub-Saharan Africa is about 65% arid and semi-arid and the proportion is even higher in West Africa. The Sahel region of West Africa[1] (comprising mainly Burkina Faso, Mali, Mauritania, Niger and Senegal as well as the northern parts of Benin, Ghana, Togo and Nigeria) are almost 100% arid or semi-arid and thus face very limiting natural precipitation. These areas also tend to be the poorest and the most food insecure parts of West Africa. That makes irrigation in the Sahelian countries an important, if not the only, option for food security and poverty alleviation, especially in this era of worldwide food, fuel and financial crises. Irrigated agriculture is the most viable means of reducing food crop failure, hunger, and malnutrition in Africa, and an effective means for improving the competitiveness of smallholder farming in the Sahel and other parts of Africa.

The Sahel region, though arid and semi-arid, has significant levels of both ground and surface water. It is reported that Niger, which is probably the most arid country in the sub-region, has a groundwater stock of about 2000 billion cubic meters and surface water from the River Niger and many small dams and rivers are yielding about 30 billion cubic meters of water annually (Woltering et. al. 2009). Similarly, Burkina Faso, Mali and Senegal abound in both groundwater and surface water.

That means the potential for irrigated agriculture in the Sahel is enormous. That potential has however not been exploited to any significant degree. Very ambitious attempts by Club du Niger in Mali and CILSS with support from Club du Sahel in the 1960s and 1970s did not achieve any

[1] Countries that officially constitute the Sahel, those in the Permanent Interstate Committee for Drought Control in the Sahel (CILSS), include Burkina Faso, Cape Verde, Chad, Guinea Bissau, Mali, Mauritania, Niger and Senegal.

significant success (Club du Sahel, 1983). Multilateral and bilateral development partners have of recent times (since 1990s) been reluctant to support irrigation development in the Sahel due to the poor performance of many past and existing irrigation projects (World Bank, 1979; Kamuanga, 1983; Dittoh, 1991).

Attempts at irrigation development by multinational river basin authorities such as the Senegal River Development Organization (OMVS) (formed by Mali, Mauritania and Senegal), the Gambia River Basin Development Organization (OMVG) (formed by The Gambia, Guinea Bissau and Senegal), The Niger River Basin Authority (NRBA) (formed by Mali, Niger and Nigeria), the Lake Chad Basin Commission (formed by Cameroun, Chad and Nigeria) and others have been largely unsuccessful (Club du Sahel, 1983). Donors and development partners have been skeptical of the viability and effectiveness of these and other large scale irrigated systems (Adam and Grove, 1984).

Experiences from earlier efforts clearly indicate serious technological, managerial, economic, political and attitudinal inadequacies, which impacted very negatively on irrigated agriculture in the sub-region. Several large and medium scale irrigation projects have been disasters (Kamuanga, 1983; Bird, 1984; Derrick, 1985; Eicher, 1986). The management of most of the irrigation projects has not been professional enough and hardly any degree of profitability can be claimed by farmers on irrigation sites in most of large formal irrigation schemes in West Africa (Kamuanga, 1982; Adams and Grove, 1984)

Since the early 1990s, attempts have been made to concentrate and develop small irrigation systems. That also is, however, yet to indicate any significant success. Recent assessment of small irrigation systems in Northern Ghana indicates “none of the existing systems can be used as an example of a success story” (Dittoh et. al. 2009). The general conclusion was that the costs outlay, even of small systems, is too high relative to the benefits and “little scientific irrigated agricultural technology is being applied in Ghanaian irrigation schemes” (Ibid).

It is however known that there are low-cost micro irrigation technologies, which have indicated considerable success in similar environments, such as in India, China and Malaysia (Postel et. al. 2001; Shah and Keller, 2002). Studies in several parts of Africa including Niger in the Sahel also indicate the high potential of micro irrigation technologies in the continent (Anderson, 2005; Pasternak et. al., 2006; Woltering et. al, 2009, Awulachew et. al., 2009).

Technical viability of technologies alone is not enough for the sustainability of technologies. Technologies must be technically, economically and socially viable. Thus, introduced technologies that can serve small farmers must be acceptable to them technically, socially and economically. Economic viability can however be only possible if crops cultivated will have markets, which can pay remunerative prices. According to Perry (1997), Sub-Saharan’s competitive edge appears to be in the production of high value vegetables and fruits. It is more so with regards the Sahelian countries of West Africa where vegetable consumption by the people is relatively high and where there has been a tradition of exporting vegetables to the more humid south and to European countries. In addition, the systems must target the need of majority of smallholding farmers, including women farmers, which will also ensure equity and effective poverty alleviation and food security in the region.

The questions that arise are:

1) Which direction (in terms of types of technology) should irrigation development take in the arid and semi-arid areas of Africa such as the Sahel, given the disappointing experiences in the past?
2) What types and levels of investments are required for sustainable irrigated systems that will address poverty concerns?
3) What roles should governments (the public sector), the formal private sector and the informal private sector (small irrigators) play?

This paper addresses these questions based on information gained from assessment of the extent of use and impacts of micro irrigation technologies in Burkina Faso, Mali, Niger and Senegal. Farmers' perceptions of the impacts of the most potentially viable micro irrigation technology on their livelihoods as well as factors influencing adoption of the technology are analyzed and relative profitability of varied versions of the technology computed. A viable and sustainable model of micro irrigation technology for the Sahelian and other arid and semi-arid zones of Sub-Saharan Africa is then proposed.

The next section of the paper discusses irrigation and poverty situations in the Sahel while the third section deals with our research findings on low cost-micro irrigation and its impacts in the Sahel. The forth section provides the comparative profitability analysis while a proposal for "micro" public-private partnerships for irrigation development is presented in the fifth section. Our conclusions are given in the last section of the paper.

II. IRRIGATION AND POVERTY SITUATIONS IN THE SAHEL

There is general lack of reliable information on irrigated agriculture in West Africa. Areas cultivated under irrigation and yields obtained by farmers quoted by policy makers and politicians in the various countries are generally "political guestimates" and can be very misleading. There is very limited reliable information on the relative importance of various irrigation systems in West Africa, thus, making it difficult to argue for or against any particular irrigation system based on already available information. What is certain is the unavailability of convincing successful models of irrigated agriculture in the sub-region.

The Food and Agriculture Organization (FAO) of the United Nations has been in the forefront of trying to compile irrigation statistics all over the world. The statistics, however, depend on what is reported by the different countries. The information with regards West Africa indicates some inconsistencies. Table 1 gives some statistics on irrigated areas and ratios of total irrigation equipped and total water-managed areas to cultivated (actual production) areas. The table indicates correctly the dominant position of Mali and Senegal with regards the development of formal irrigation in the Sahel and the fact that even in arid areas, such as the Sahel, irrigated area is less than 30% of the irrigation potential. A contradiction, however, is with regards areas under formal and informal irrigation. The table indicates that informal irrigation is relatively insignificant in all the countries except Burkina Faso. It is only in Burkina Faso that the cultivated area (formal and informal) exceeds the total irrigation equipped (formal) area. Experiences in the field however indicate that in all the countries, informal irrigated areas by small irrigators along riverbanks and dams are very substantial. Indeed the areas under informal irrigation in Niger and Senegal could also exceed those under formal irrigation. The contribution of informal irrigation to the economies of West African countries seems to be grossly underestimated. There is need for structured assessments of areas and production under informal irrigation in West Africa.

Table 1: Irrigated areas and ratios of equipped and water-managed areas to cultivated areas*

Country	Irrigated areas (ha) (Areas equipped for irrigation i.e. formal irrigation)	Shares of irrigation potential (%)	Ratios of total irrigation equipped (formal) areas to total cultivated areas	Ratios of total water-managed areas (formal and informal) to total cultivated areas
Burkina Faso	25,000	15	0.6	1.1
Mali	235,791	42	4.9	6.1
Niger	73,663	27	1.6	1.9
Senegal	119,680	29	4.8	6.0

*Irrigation equipped areas are those developed (formally) which may or may not be under cultivation presently. Water-managed areas are the irrigation equipped areas plus areas in which water is managed informally for irrigation (i.e. formal and informal areas). Cultivated areas refer to the actual areas cultivated under irrigation.

Sources: FAO (2005) AQUASRAT database, Svendsen et. al. (2009).

Poverty reduction has taken centre stage in all countries and especially in developing countries where the global food and financial crisis is expected to worsen unemployment and poverty (Blankenburg and Palma, 2009). Indeed the thinking of several policy analysts is the need for drastic restructuring of the world economy towards a “viable, progressive and more egalitarian” system (Wade, 2009) to curtail future economic crises. Thus, there is need for emphasis on equity and the needs of resource-poor households in the pursuance of development. Table 2 gives the levels of poverty in the Sahelian countries. These levels are very high, even by West African standards, and there is urgent need to reduce the numbers of the poor. The high percentages of the populations in agriculture clearly indicate the dominant role agricultural development will play in poverty reduction in the countries. The role of well functioning irrigation systems in poverty alleviation has also been well documented especially for Asia (Datt and Ravallion, 1998; Hasnip et. al., 2001; Lipton and Litchfield, 2002; Bhattarai and Narayanammorthy, 2003). Africa should, therefore, also be able to tackle its poverty and food insecurity problems through well-designed and sustainable irrigated agricultural systems, which must include putting in place relevant social and physical infrastructures.

Table 2: Poverty levels in the four Sahelian countries

Country	National poverty level (% population below poverty line)	Rural poverty level (% of rural population below poverty line)	Economic active population in agriculture (%)
Burkina Faso	46	52	92
Mali	64	76	97
Niger	63	66	87
Senegal	33	40	72

Source: World Bank (2008): World Development indicators

III. MICRO IRRIGATION TECHNOLOGIES AND THEIR IMPACT IN THE SAHEL

This section is derived largely from the assessment of the extent of use and impacts of micro irrigation technologies in the four Sahelian countries (Dittoh et. al., 2010). Details of the methodology of research may be obtained from that research report. Suffice it to state here that participatory rural appraisal (PRA) and participatory impact assessment (PIA) tools were used to obtain information from about 200 small irrigators in 22 communities in the four countries. As stated by Catley et. al. (2008), PIA allows impact to be measured against qualitative indicators such as changes in dignity, status and well-being or changes in the level of community participation. In addition, impact assessments of development and technological interventions have “shifted away from purely technocratic and expert-oriented towards stakeholder-inclusiveness and participatory assessment” (Dietz et. al. 2009).

Micro irrigation technologies in the Sahel may be broadly categorized into four as given in Table 3. The table gives small irrigators’ perceptions of the relative use of water lifting systems for irrigation in the various countries. It indicates that the traditional bucket/calabash/ watering-can technology plays a dominant role (used by over 80% of the people) in irrigated agriculture in the communities. The table also indicates that the motorized pump system is more commonly used than the manual pump system. When irrigators were asked to give scores for the technology systems they would prefer, almost all the irrigators in all the countries indicated preference for motorized pumps as opposed to bucket/calabash/watering-cans or manual pumps. They however pointed out that a main disadvantage of the motorized pump is the high cost of fuel (petrol and diesel). At present, most of the farmers in the surveyed sites use various combinations of water lifting methods to get water from water sources to crop fields. The problem with all of them, to varying degrees, is the inefficiency in water use in this water scarce region. Various versions of drip irrigation (goute-a-goute) have been introduced recently into the region to solve the water scarcity as well as other crop production problems. Those technologies are at various levels of adoption across the four countries surveyed.

Table 3: Micro irrigation technology types in use in the surveyed communities in the Sahel, 2009

Broad Micro Irrigation Technology Categories (Water lifting systems)	Irrigators' perception of the frequency of use of technology categories amongst the people (%)				
	Burkina Faso	Mali	Niger	Senegal	All four countries
Bucket/calabash/watering can system	84.3	86.7	85.0	77.5	83.4
Manual (pedal/hand) pump system	1.7	4.7	3.0	2.0	2.9
Motorized pump system	9.0	6.3	9.0	17.5	10.5
Gravity/Canal System	5.0	2.3	3.0	3.0	3.3

Source: Field Survey, November-December 2009

One of the main drip irrigation technologies introduced recently into the Sahel region is the "African Market Garden" (AMG). It is a technology, which combines water management with improved crop production practices. It has been designed, adapted, and popularized in several West African countries by the Sahel Programme of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Niger (see Pasternak et. al. 2006; Oumarou, 2008; and Woltering et. al. 2009). Since 2006, AVRDC-The World Vegetable Center based in Taiwan, has also collaborated with the Sahel Programme, and the AMG is now being jointly popularized by the two research centers. The water management technology component is supported by ICRSAT and the vegetable cultivation and improved practices components are provided jointly by ICRISAT and AVRDC.

All of the water lifting systems in Table 3 can be used in low-cost drip irrigation. In Niger, the AMG technology is basically of the motorized pump concrete reservoir-based system. The same AMG system is also quite common in Burkina Faso. Over 500 of such AMG sets were constructed in Burkina Faso in the early 2000 under a donor-funded project. The project gave the drip irrigation sets free of cost to the farmers and the farmers constructed the cement water tanks with their own funds. Several of the small irrigators that were interviewed regarded this technology as largely suited for relatively rich farmers. They observed that an initial investment of about 500,000 CFA francs (about US$1,100) is required for the installation of the system and so it is out of reach of majority of the smallholder farmers in the region. Another version of the AMG technology uses the barrel system instead of the concrete water reservoir. The barrel-based system is much more common in Senegal and is also being introduced into Burkina Faso and Mali. That AMG version is much cheaper than the concrete reservoir-based system, but it also usually requires a borehole or permanent well and motorized pump and installation of the whole system is still beyond the investment abilities of average smallholder irrigators in the region. Most of the small irrigators fill the barrels by fetching water with buckets and that is very laborious.

Several research reports and papers, feature articles and news reports have, recently, alluded to the potential of drip irrigation to "alleviate hunger and poverty" (Postel et. al. 2001), to "turn gravel into green" (USAID, 2005), to "enhance food security" (Burney et. al. 2009), to "break Africa's hunger cycles" (Lewis, 2010), and to "get more from less" (Kidambi, 2010). Also several studies in the past have reported the many advantages of drip irrigation as noted earlier. What is important now is contributions towards the realization of the potentials that exist in the technology for Africa, especially in these times of global food and financial crises.

In Table 4, we provide an analysis of farmers' perceived impacts of the technology on them and their family members. These perceived impacts of the technology are actually short-term impacts of technology interventions, as impacts of the technology are documented only on immediate level effects. The table gives average farmers' scores with respect to impacts of AMG technology on key aspects of farming. The last column in the table ranks the "after adoption" impacts. It indicates that, on the average, for all the four countries, the highest impact of the AMG had been the "willingness to pay for the technologies" followed by the "better (more efficient) use of water resources". Willingness to pay is definitely as a result of ability to pay. The indication therefore is that the technology is profitable to them. The best ten impact indicators have been ranked in the table. Some of the individual country rankings were quite different from that of the aggregate ranking. In the case of Niger, for example, the "better use of water" was the most important impact followed by "increase in the number of vegetables cultivated". For Senegal, "increase in crop yields" was the most important realized impact followed by "better use of water". Also, market development as a result of the introduction of the AMG technology in a place, was regarded as a very important contribution of AMG in Senegal (score of 8.9), but it was the opposite case in Mali (score of 2.5). So many factors, including how the systems are organized and supported in a country, are responsible for the wide variation in the scores of impacts across the various factors.

Difference between the “before (the technology)” scores and the “after (the technology)” scores in fact capture the extent of the perceived impacts of the technology as realized by the farmers. Those are given in the last column of Table 4. The results clearly show that, the largest positive change occurred with regards to “savings in time” followed by “better use of water” and then “crop yields”. It is interesting that “willingness to pay”, which ranked highest in the case of the absolute scores, is not anywhere near the best when changes are considered. This means that farmers’ willingness to pay for a technology has been almost the same, but quite high, over time. That may be a sign that introduced technologies in the past have been quite beneficial to them and, thus, they have always had a high willingness to pay for technologies. There are, however, quite wide differences between countries when the individual country scores are used to compute the differences. This could be due to the relatively small sample size (per country) that was used in the survey. The findings are, nevertheless, interesting in terms of gauging the overall farmers’ views and for planning a thorough policy analysis work in the sector.

The decision to accept to use and finally adopt a technology is a process that takes time to reach the full scale of adoption. The influences of various factors in the adoption process, however, vary by place (country, agro-ecological region), farmers’ characteristics, and by time. We found that farmers were aware of the relative importance of various factors affecting the adoption process of the technology. Table 5 gives farmers’ scores with regards influence of various factors on drip irrigation (AMG) technology adoption.

It is very revealing that irrigators regard acquisition of knowledge and subsidy on irrigation equipment (and the system) as the two factors with the greatest influence on their decision on whether to use or not to use the drip irrigation technology. The ten most important factors influencing the decision to adopt the drip (AMG) technology, as perceived and stated by the farming communities surveyed, have been ranked and the results are presented in the last column of Table 5. The ones with almost negligible influence are tax on irrigation equipment, distance from market and age. The explanation given with regards the negligible influence of tax on equipment is that farmers are, so far, unaware of taxes on the equipment.

Table 4: Farmers' perceptions of impacts of drip ("African Market Garden") irrigation technology (Score of 10 is best and 1 is worst)

Indicator		Average Scores					Rank of Benefits after adoption	Difference on score**
		Burkina Faso	Mali	Niger	Senegal	All four countries		
Increase in area under vegetable cultivation	*Before	5.1	7.0	5.2	4.3	5.4		1.2
	***After**	**6.0**	**5.5**	**7.3**	**7.5**	**6.6**		
Increase in crop (vegetable) yields	Before	3.2	6.3	5.5	5.6	5.2		2.6
	After	**6.4**	**6.9**	**7.8**	**9.9**	**7.8**	**4th**	
Number of types of vegetables cultivated	Before	7.4	7.3	6.0	6.2	6.7		1.2
	After	**7.2**	**7.4**	**8.3**	**8.7**	**7.9**	**3rd**	
Number of times vegetables are cultivated	Before	4.6	5.6	5.5	5.7	5.4		2.3
	After	**7.8**	**5.8**	**7.8**	**9.5**	**7.7**	**5th**	
Quantity of male labor employed in off-season	Before	6.7	6.5	6.5	7.1	6.7		-2.1
	After	**4.5**	**6.1**	**3.3**	**4.5**	**4.6**	**Least impact**	
Quantity of female labor employed in off-season	Before	5.5	7.6	5.7	6.9	6.4		-0.4
	After	**6.8**	**5.7**	**4.1**	**7.3**	**6.0**		
Better household food security	Before	3.6	6.8	5.1	6.2	5.4		1.7
	After	**5.1**	**6.8**	**7.5**	**8.8**	**7.1**	**8th**	
Higher household income from irrigated production	Before	4.6	5.5	4.5	6.2	5.2		2.2
	After	**6.6**	**6.1**	**7.6**	**9.3**	**7.4**	**6th**	
Better community unity	Before	3.8	4.5	6.1	6.5	5.2		1.6
	After	**5.6**	**4.8**	**7.4**	**9.5**	**6.8**	**9th**	
Better community well-being	Before	3.4	6.2	4.6	6.2	5.1		1.6
	After	**4.1**	**6.7**	**7.3**	**8.8**	**6.7**	**10th**	
Better use of water resources	Before	2.5	3.6	3.5	3.1	3.2		4.9
	After	**6.8**	**6.8**	**9.2**	**9.7**	**8.1**	**2nd**	
Savings in time	Before	1.6	2.8	2.5	2.3	2.3		5.1
	After	**7.5**	**6.2**	**7.4**	**8.6**	**7.4**	**6th**	
Market development of produce	Before	3.5	2.1	4.3	5.5	3.9		2.0
	After	**5.6**	**2.5**	**6.4**	**8.9**	**5.9**		
Willingness to pay for technology	Before	7.6	6.8	6.8	6.6	7.0		1.5
	After	**7.9**	**7.7**	**8.6**	**9.6**	**8.5**	**1st**	

*"Before" and "after" refer to before and after the adoption of the drip (AMG) irrigation technology

**Difference on score: Difference between "After" score and "Before" scores, which captures changes on the corresponding variable brought by the technology.

Source: Field Survey, November/December 2009

Table 5: Average farmers' scores of the influence of factors affecting adoption of drip irrigation technology in the surveyed communities, 2009

Influencing Factor	Average Farmers' Scores (10 is great influence, 1 is negligible influence)					Rank
	Burkina Faso	Mali	Niger	Senegal	All four countries	
Age	5.3	6.1	5.5	1.7	4.7	3rd least
Sex	7.7	8.2	9.0	5.6	7.6	8th
Type of vegetable crop	7.0	7.0	7.2	6.1	6.8	10th
Size of irrigated area	10.2	8.9	8.3	8.9	9.1	3rd
Ownership of irrigated land	4.8	5.5	5.0	5.6	5.2	
Farming experience	5.3	4.8	6.3	5.3	5.4	
Irrigation experience	6.0	5.1	4.7	5.4	5.3	
Training	10.0	10.0	9.7	9.9	9.9	1st
Simplicity of technology	8.8	9.6	9.1	8.0	8.9	5th
Rainfall pattern	7.7	9.1	9.6	9.4	9.0	4th
Availability of market	4.8	9.3	9.5	9.0	8.2	6th
Distance of market	2.8	3.0	3.1	2.8	2.9	2nd least
Availability of production inputs	9.1	8.3	7.3	5.8	7.6	8th
Credit availability	6.8	8.3	4.9	6.1	6.5	
Family labor availability	4.5	5.6	5.8	6.1	5.5	
Hired labor availability	3.4	5.6	5.7	6.0	5.2	
Subsidy on irrigation equipment (and technology)	10.0	9.9	10.0	9.8	9.9	1st
Tax on irrigation equipment	1.0	1.2	2.0	2.5	1.7	Least
Access to river, dam or dugout water	7.7	8.0	8.2	7.2	7.8	7th

Source: Field Survey, November/December, 2009

It is surprising that credit availability and availability of markets were not regarded as the most important determinants of their decisions to adopt the technology. That might be because of the influence of governmental and non-governmental organizations which offer them support in various forms. Their scores (6.5 and 8.2 respectively) are however quite high. That indicates their importance.

All except three of the factors in Table 5 scored 5 (i.e. 50%) or above (aggregate score) indicating that farmers take very many factors into consideration in their decisions to adopt or not to adopt irrigation technologies. Thus, interventions to expand adoption and dissemination of the technology will have to target issues that farmers regard as important factors affecting their decision making with regards the technology.

IV. COMPARATIVE PROFITABILITY ANALYSIS OF MICRO IRRIGATION SYSTEMS IN THE SAHEL

Comparative profitability analysis was undertaken for several micro irrigation systems including non-drip irrigation systems in the four countries. Table 6 is an example of the kind of comparative analysis that was done for the four countries. It is the Burkina Faso case. Table 7 gives the most profitable (in terms of financial profitability) of the micro irrigation systems in the various countries. They are all different versions of the AMG technology system. Thus the drip (AMG) technology is clearly superior in terms of profitability to the other micro irrigation systems practiced in the various countries. It also has so many other advantages as alluded to earlier.

Table 6: Gross margins and net annual returns of micro irrigation systems in Burkina Faso

*Irrigated system	CFA Francs							Net annual return in US$
	Investment costs	+Depreciated value of investment costs	Irrigators annual operational costs	Total revenue	Gross margin	Pay back period	Net annual return	
BF1	779,000	155800	214,125	597,500	383,375	2.03	227,575	494.73
BF2	377,400	75480	196,500	488,000	291,500	1.29	216,020	469.61
BF3	454,000	90800	213,500	408,750	195,250	2.33	104,450	227.07
BF4	196,300	39260	202,500	340,750	138,250	1.42	98,990	215.20

* BF1: AMG Permanent Well, Motorized pump, Concrete Reservoir System
BF2: AMG Permanent Well, Bucket Fetch-to-Barrel System
BF3: Permanent Well, Motorized Pump, Basin System
BF4: Permanent Well, Bucket Fetch-to-Watering Can System

+Assumption is 5 year shelf life for all investment items with no salvage value and straight line depreciation.

Source: Computations from Nov/Dec 2009 Field Survey Information

Table 7 indicates very wide differences in net annual returns from the best profitable versions of the AMG system in the various countries. It can be said to be attributable greatly to the level of technical knowledge given to the irrigators, the organization of the systems with regards technical and extension support, the business orientation of the irrigators, the degree of innovativeness with regards to problems that arise and the volatility in prices typical of vegetables. The excellent technical backstopping given to Senegalese irrigators by governmental and non-governmental organizations is largely responsible for the very high profitability obtained by them.

Table 7: Most profitable drip irrigation systems in the various countries*

Country	Description of the most profitable (in terms of financial profitability) micro irrigation systems in Sahel countries	Computed net annual return per 500m^2 area of vegetables (CFA francs)	Net annual return in US$
Burkina Faso	AMG Permanent well, motorized pump, concrete reservoir system (Individual)	227,575	494.73
Mali	AMG Permanent well, pedal pump, barrel system (Individual)	61,860	134.48
Niger	AMG Permanent well, motorized pump, concrete reservoir system (Individual)	110,510	240.24
Senegal	AMG Permanent well, motorized pump, barrel system (Group[+])	464,660	1,010.13

*Analysis was done for several drip and non-drip micro irrigation systems
[+]Members of the groups cultivate their own individual plots
Source: Computations from Nov/Dec 2009 Field Survey Information

V. A CASE FOR "MICRO" PUBLIC-PRIVATE-PARTNERSHIPS?

There are, no doubt, numerous advantages of drip irrigation, especially the African Market Garden version, but at the same time, there have been very limited dissemination of the technology through local market transactions. The important reason for the low level of dissemination (voluntary purchase of the technology), by our judgment, is the relatively high cost of establishing a viable, effective, and sustainable smallholder drip irrigation system. Awulachew et al. (2009) reported that conventional drip irrigation systems costs US$5,000 – 10,000 per hectare or more to establish in East Africa but there are simple systems that can cost as low as US$15 to cover 15m^2 or US$200-400 to cover 500m^2. The set up costs, of AMG versions being promoted in the Sahel, range from about 400,000 to 800,000 CFA francs (about

US$870-US$1,700)[2] (Dittoh et. al. 2010). There are also drip irrigation sets that are much cheaper than the AMG versions described above. Such systems include those using household buckets, barrels, or plastic tanks of 500-1000 liter capacities. They have the advantage of affordability in the region. It is, however, doubtful if they can be viable in the medium to long term. There is need to look for systems that will meet the development aspirations of nations that are being threatened by chronic food crisis and increasing poverty trends.

In this context, it is necessary to look at various Public-Private Partnership (PPP) models of investments to see how they can be modified and used to promote drip irrigation agriculture in the Sahel and other parts of Africa. An adaptive form of micro PPPs may be what is needed, since the huge investments of existing PPPs are not what are required for development of drip irrigation systems for smallholder irrigators.

PPPs have typically ignored the agricultural sector to a large extent especially in Africa (Farlam, 2005). Even the World Bank sponsored PPPs in infrastructure has not extended its activities to any significant degree to infrastructure in the agricultural sector (World Bank Institute, 2008). This may partly be because of the conclusions reached with respect to irrigation infrastructure in Africa which claim, among other things, that it is too expensive to invest in irrigation in Africa (Adams and Grove, 1984).

The conventional definition of PPP is “a contract between a public sector institution and a private party, in which the private party assumes substantial financial, technical and operational risk in the design, financing, building and operation of a project” (PPP Manual, South Africa, 2004). Several governments around the world have embraced PPPs because additional resources are usually made available to meet the many huge investments expected of them. Also there is usually increased efficiency in project delivery and operations through the PPPs. In practice, PPPs range from simple management contracts which may require no investment of funds to build-operate-transfer (BOT) models. All PPPs are, however, guided by very clear legally binding rules and regulations on the responsibilities and obligations of the partners. The appeal of PPPs is their ability to leverage the strong areas of the public and private sectors to ensure efficiency, accountability, business ethics and benefit to all stakeholders.
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The application of PPP to the development of irrigation in Sub-Saharan Africa, will require far-reaching modifications of conventional PPP models developed for large-infrastructural projects. This is because of the kinds of parties involved (smallholder farmers) and the goals (poverty alleviation) being pursued. Firstly, a drip irrigation PPP arrangement will involve the relevant sector agency of government, small farmers in groups (‘informal’ private sector) and the formal private sector, thus, it is a PPPP (or PP_iP_fP, that is, public-private (informal)-private(formal) partnership) that has to be formed to be able to obtain the benefits of the partnership. Even if

[2] Actual costs obtained in the field in 2009

governments can provide the funding, there is need to contract management firms in a PPP fashion to provide effective backstopping. Secondly, the farmers (irrigators) that should participate must be members of strong local farmer groups. Strong farmer groups do not exist yet in the Sahel and many other African countries, and thus Government agencies and NGOs have to initiate formation of such groups and build their capacities. Thirdly, the infrastructure that should be invested in should be categorized into two: a relatively large permanent well (or borehole), motorized (electric or solar) pump barrel-based system for groups of resource-poor smallholders and the concrete reservoir-based system for individual medium scale producers . The systems in place at Kuer Yaba Diop in Thies Region and Ngoha Ndioffogor in Fatick Region of Senegal, which are supported by governmental and non-governmental organizations, are examples of the suggested system for smallholders. This proposed model implies acquisition of relatively large contiguous areas of land where all irrigators will have a couple of barrels to irrigate their individual plots. Fourthly, the formal private sector partner, who may or may not invest funds in the irrigation project, should take the responsibility of backstopping production, processing (if necessary) and marketing of the farmers' produce by building the capacity of the irrigators and local people in skills and knowledge, possibly with support from both private and public sources. The farmers' should however have control of their own production, processing and marketing and how to appropriate returns. A system should however be put in place for part payments at every harvest towards cost recovery of the investment and maintenance and replacement of equipment. There is no doubt that such a system will demand a good administrative and accounting system. Indeed the micro PPPs for micro irrigation will be basically agribusiness enterprises providing the drip irrigation technology but also supporting range of inputs to vegetable and other farmers (irrigators).

VI. CONCLUSIONS

In this era of global food and financial crises and climate change, which adversely affect precipitation and in turn agricultural productivity in dry land areas, irrigated agriculture in Africa, especially in the arid and semi-arid parts, is a must. The experience of irrigated agriculture in most parts of Sub-Saharan Africa had been highly discouraging. Presently, the drip irrigation technology is being promoted in many parts of Africa and particularly in the West African Sahel under several names. The African Market Garden (AMG) is among the prominent ones. There are various advantages of the AMG technology, including very efficient use of water and fertilizer, savings in time, increase in crop yields and flexibility in production so that cultivation can be done to coincide with scarcity (of produce) and hence high prices, among others.

The emphasis of any irrigation development in Africa must be long-term viability and sustainability, and the needs of different categories of farmers; resource-poor smallholder farmers as well as medium scale farmers. The better off and well-to-do farmers may be served better by effective operation of the privately operated market and privately operated input suppliers. Public support and any form of subsidy (drip kits or other irrigation equipment) should target smallholder and resource-poor farming communities.

The West African Sahel has experienced severe food shortages, indeed famines, in the past and indications are that unless drastic measures are taken to increase food production in the area, millions of people will continue to be at risk of famine. The global food and financial crises have only exacerbated an already growing problem in the region. To tackle the twin problems of low level of food production (food insecurity) and increasing poverty, there is need to take advantage of resources and promising technologies that exist. Micro irrigation technology, in various forms and with various trade names, has the potential to drastically reduce poverty of households in the Sahel. Introduction of micro irrigation in several countries in the Sahel, including Burkina Faso, Mali, Niger and Senegal (in the form of African Market Garden), has been widely acclaimed by irrigators as being suitable for the arid environment, and has shown to be profitable to the farmers with convenience (higher impacts) on several farming related factors. The cost of establishing a viable, sustainable and effective smallholder drip irrigation system (in the form of an African Market Garden) is however above the capabilities of average small farmer groups in Africa now. This implies that there is need to institute modified public-private partnership (micro PPP) modules for drip irrigation technology dissemination in Africa. The micro PPPs are to ensure that funding for the technology will be adequate, and that viable, sustainable and poverty alleviating microirrigation systems can be established as per the specific need and demand of Sub-Sahara African countries.

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