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Chapter 7

MICRO IRRIGATION-BASED VEGETABLE FARMING FOR INCOME, EMPLOYMENT AND FOOD SECURITY IN WEST AFRICA

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ABSTRACT

Dry season smallholder irrigated vegetable production in the arid and semi-arid parts of the West African sub-region has been an important income generating activity and a means of engaging productive labour for many decades. Crop production has often been on less than half an acre per irrigator due to several constraints including low watertable in the case of shallow well irrigators; poorly constructed dams, silting rivers and streams and water lifting constraints in the case of surface water irrigators; and limited market opportunities, among others. The resultant output per person, and thus income generated per worker, has been very low with high risks of unsustainable production. Attempts at "modern" irrigation systems in the sub-region have been largely unsuccessful but some of the micro irrigation systems operated by smallholders seem to be performing satisfactorily. That is an indication that "affordable micro-irrigation for vegetables" (AMIV) systems could be the answer for improving irrigated vegetable production in West Africa.

This chapter examines the current issues of irrigated agriculture in the West African sub-region with particular reference to the potential of irrigation for income generation, employment and food security and suggests possible "growth paths" for irrigated vegetable production. It draws attention to the agribusiness potential that exists for all actors along the irrigated vegetable value chain.

The paper is based on a comprehensive literature review of smallholder irrigation in several West African countries, particularly Nigeria and the Sahel countries, as well as a

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participatory rural appraisal field surveys in Burkina Faso, Ghana, Mali, Niger and Senegal. The paper argues for concerted effort by the governments and the private sector (smallholder irrigators and agribusiness concerns) of countries in the dry areas of West Africa to systematically develop micro irrigation systems identified by this and other studies. There is great potential for their use to increase the incomes of smallholder farmers, including women and the employment of the youth in rural and urban areas. They are also important in ensuring food and nutrition security in both rural and urban areas in the West African sub-region.

Keywords: Water management, smallholders, gender, value chain management, income generation, food and nutrition security

1. INTRODUCTION

Improving human well-being through sustainable increases in production, employment and food security is a key goal of development policy in all countries especially in poor developing countries. Countries in the West African sub-region are generally poor but the poorest parts are the arid and semi-arid areas. Those areas are generally characterized by poor infrastructure, very low levels of agricultural productivity, food insecurity and famines in very bad years. The availability and accessibility of nutritious food in quantity and quality all year round in households in these areas of West Africa has been the exception rather than the norm for many decades. According to Swift and Hamilton (2003), "the naturally most food insecure environments in Africa are the arid and semi-arid zones, where drought is a major recurring risk".

The arid and semi-arid areas of West Africa cover about 65% of the land area of West Africa and contain about one-third of the population. Over 80% of the working people of the region are smallholder farmers and herders (ICID, 2011). Crop production is largely dependent on rainfall and households cultivate relatively small land areas, of about half hectare to two hectares on average (Drechsel et. al. 2004, Eastwood et. al. 2006). The rainy season is relatively short (April/May to August/September) and rainfall is very erratic, thus droughts and floods, even within the same year, are common. There is considerable disguised unemployment especially in the long dry season which is a major reason for the persistent food insecurity and poverty in the sub-region.

It has been pointed out by several previous studies that the contribution of irrigated agriculture to food and nutrition security, increased employment and poverty alleviation is very significant in many parts of Asia (Postel et. al. 2001; Bhuttarai and Narayanmoorthy, 2003; Hussain and Hanjra, 2004), and also in several parts of Africa (Dittoh, 1997; Ojo et. al, 2011). It has even been stated that there is need to invest to double the irrigated area in Sub-Saharan Africa, from 6.4 million hectares in 2000 to 12.8 million hectares in 2015, if the first Millennium Development Goal of halving poverty and hunger (MDG 1) is to be achieved (Commission for Africa, 2005). The performance of irrigation systems in Sub-Saharan Africa and especially in West Africa has however continued to be very disappointing. The failure of "modern" irrigation systems in the sub-region has been discussed extensively (Dittoh, 1991a, 1997; Sarris and Ham, 1991; Musa, 1991; Mariko et. al. 2001; Balmisse et. al. 2003) and most irrigation schemes are still to prove successful after several rehabilitations and redesigning. Office du Niger, the oldest and largest formal irrigation system in West Africa, achieved very little until it underwent privatization and price liberalization reforms in the 1980s (Mariko et. al. 2001).

The other large schemes such as the Bakalori, Hadejia, Tiga, Challawa Gorge and Goronyo in Nigeria and the Tono and Vea irrigation schemes in Ghana have their own stories of failure. These large systems targeted rice, wheat, tomato, pepper and to a smaller extent maize and sugar production. The main reason for failure may be summarized as top-down decisions with regards to the types of physical (engineering and agricultural) as well as governance systems; which resulted in faulty engineering works, very poor irrigation governance, very little agricultural scientific input, very high development costs, among others.

Attention shifted to small scale irrigation systems since the1980s mainly because small informal systems continued to play significant role especially in the production of vegetables (tomatoes, pepper, okra and others) when the large formal systems were unsuccessful. Except for the case of Nigeria, where the use of small motorized pumps by smallholder informal irrigators increased significantly, the shift in attention does not seem to have had much effect on irrigated production in the countries because the traditional "bucket and calabash" system continues to be predominant as revealed by recent surveys (see for example Dittoh et. al. 2010). The "watering can" is however gradually replacing the "bucket and calabash" but there is very little difference between them with regards to the productive capacity. Women irrigators in the sub-region however revere the "watering can" because "they are yet to see any appropriate irrigated technology that can replace it" (Akuriba et. al. 2010). Can the watering can technology ensure food security, employment and increased incomes in West Africa? What technologies are available and affordable or can be made affordable for smallholder vegetable irrigators to increase productivity in the arid and semi-arid areas of West Africa? What organizational systems can remove bottlenecks with respect to marketing, processing (if need be) and increased consumption to ensure sustainability of irrigated vegetable production?

Also, various economic and investment analyses point to the profitability and viability of both large scale and small scale irrigation systems (Dittoh, 1991b). For instance, You (2008) showed that some large scale schemes in Sub-Saharan Africa will result in much higher profits, but the potential for profitable small-scale irrigation is about 10 times greater than that for large-scale irrigation.

But what kind of profitable small systems will be affordable and acceptable to poor smallholder farmers? Can poor small farmers be organized to take advantage of irrigation technologies that are good for smallholders but may be quite expensive (not affordable)? These questions are being examined in this Chapter.

2. The Study Area and Methodology of Research

The West African sub-region comprises of 17 countries, namely; Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, St Helena, Senegal, Sierra Leone, and Togo. The areas that constitute the arid and semi-arid part of the sub-region include all the countries that constitute the Sahel, namely Burkina Faso, Cape Verde, Chad, Guinea Bissau, Mali, Mauritania, Niger and Senegal as well as the savanna areas of Benin, Ghana, Nigeria and Togo.

The discussion in this Chapter however concentrates more on Nigeria and Mali (countries with the largest irrigated area) as well as Burkina Faso, Ghana, Niger and Senegal (countries in which field surveys were carried out). The combined population of these countries is over 90% of the total West African population.

The West African arid and semi-arid zone faces considerable water stresses during large part of the year. Rainfall in the whole area is not only erratic but also seems to be getting worse with the changes in climate. According to Hulme (1996), “the dry Sahelian region has been most affected by rainfall changes, having experienced a decrease of 20-30% in expected annual average rainfall between the periods 1931-1960 and 1961-1990”.

Almost all the West African countries are in the low-income bracket (that is per capita GDP of less than US$900) and also rank low on the United Nations Human Development Index and the OECD’s Human Poverty Index. More than two-thirds of the population lives in rural areas and relatively large proportions live on incomes of less than $1 a day.

Despite the obvious need for the development of irrigation in the West African sub-region, especially the arid and semi-arid parts, public and private sector investments in irrigation in the sub-region over the years have been inadequate. That is why the Commission for Africa (2005) called for the doubling of Africa’s irrigated area by 2015.

Reviews of investments in some river basins in Africa indicate that considerably more investments are required to exploit their potential. Hanjra and Gichuki, (2008), for example, noted that less than 4 percent of Africa’s internally renewable water resources are developed and have advocated increased public investment in water resources management for ending hunger and extreme poverty.

This Chapter is based on analyses of irrigation information from various secondary sources, and results obtained from a participatory rural appraisal (PRA) and participatory impact assessment (PIA) field study in 2009 in selected irrigation communities in Burkina Faso, northern Ghana, Mali, Niger and Senegal. Details of the methodology of the field study are given in Dittoh et. al., (2010).

Farmers’ perceptions of the impact of micro-irrigation technologies on vegetable production, employment, community well-being, local governance, gender relations and other factors were assessed based on focus group discussions. Quantitative information on investments, use of inputs, outputs and incomes were obtained from farmers in both the focus group discussions and individual interviews in the selected communities.

3. Current State of Irrigated Agriculture in West Africa

Irrigation in West Africa constitutes a very small proportion of crop production. Irrigated production contributed only 0.9% and 2.3% of the total production of grains and vegetables respectively in 2004 in Nigeria (FAO/ENPLAN Group, 2004), the country with over 58% of the total irrigated area in West Africa. The contribution in smaller countries and especially in the Sahel countries is however much higher, especially with respect to vegetables in Burkina Faso, Mali, Niger and Senegal as well as rice in Mali. The overall estimate of irrigated contribution to agricultural production in West Africa is about 3% (FAO, 2005). It must however be much higher with respect to vegetable production since irrigation in West Africa is almost synonymous with vegetable production. More recent estimates are not available but if the historical trend is anything to go by, it is unlikely there is any significant change.

The lack of reliable data on irrigation in Sub-Saharan Africa continues to be a serious problem. There are no systematic efforts in data collection and recording on irrigated areas in the sub-region. In recent times, however, information on formal (public) irrigation systems (large/medium scale as well as small scale) have improved somewhat in some countries but that on informal irrigation, the area of which is thought to be at least four times that under formal schemes in most of the countries, are largely "intelligent guesses". Estimated areas under irrigation in the various West African countries are reported in Table 1. Data related to areas under formal systems are estimates obtained from FAO sources (Doll and Siebert, 1999) while areas under informal irrigation are estimates from Dittoh (1997) with the assumption that there has not been significant increase in informal irrigation within the last 15 years. With increase in population, there is the likelihood of increase in area under informal irrigation; however, it is also the case that there are reductions in both surface and groundwater availability in many parts of the sub-region. Many rivers and streams have been drying up due to siltation and misuse. Thus, the assumptions used in Table 1 are realistic and the situation on the ground in the sub-region attests to that. Areas under irrigation in Nigeria and Mali constitute about 70 percent of the total irrigated area in West Africa as illustrated in Table 1. Rice is popularly cultivated in most of the large-scale formal systems, whereas, indigenous and exotic vegetables are the preferred choice in the informal irrigation and small-scale formal systems.

The dominance of informal irrigation in the sub-region is also clearly illustrated in Table 1, even though there is a need to be cautious with some of the estimates. In the case of Nigeria, for example, our estimated area under public irrigation is about 17.7% of the total irrigated area (Table 1), whereas an estimate by FAO/The ENPLAN Group (2004) is 13%. Some of these inconsistencies and anomalies are, however, understandable, given the problems in availability of reliable irrigation data from national censuses in many of the countries.

Nigeria is probably the only country in the sub-region with a comprehensive programme to improve informal irrigation through the National Fadama Development Project (NFDP Phases I, II and III). The programme is supported by the World Bank and the African Development Bank. "Fadama" is gradually becoming synonymous with indigenous (informal) system of irrigation in northern Nigeria. The word actually refers to low lying areas that are flooded during the wet season and are used for irrigated production during the dry season. The NFDP basically promotes the use of tubewells as well as surface water and provides pumps (on hire purchase basis) and technical knowledge to expand irrigation access and improve upon the indigenous system. That probably explains the very wide acceptance of the programme; an indigenous knowledge system (IKS) has been the basis of the programme.

An evaluation of NFDP Phase II indicated that, compared to the situation before, 10%, 43.3% and 47.0% of Fadama irrigators respectively said they had little, high and very high improvements in their farm incomes (Kudi et. al. 2008). Another recent study showed that while 16 percent of Fadama II farmers invested in irrigation pumps, only 2% of non-Fadama farmers did so (Takeshima et. al. 2009). Again, Abric et. al. (2011) have stated that participation in the Fadama II project increased the value of individual productive assets by

49 percent while the value of productive assets owned by groups of beneficiaries increased by 590 percent.

An emerging problem with respect to the Fadama programme is the falling watertable in many areas. Given the experience of some States of India with regards to use of tubewells, this is a problem that should be confronted by groundwater experts. Though India is the world's largest user of groundwater for irrigation (Siebert et al., 2010), there are States in India such as Gujarat that "buried the corpses of tubewells" because of the harm it caused to the people in the past (Jagawat, 2012). The falling ground watertable in the State of Gujarat, for instance, is one of the severe water related issues in India.

Table 1. Estimated Areas under Formal and Informal Irrigation in West African Countries*

Country	Area under irrigation (hectares)		
	Formal systems	Informal systems	Total
Benin	9,786	11,000	20,786
Burkina Faso	43,000	23,000	66,000
Cape Verde	2,779	14,000	16,779
Chad	14,020	27,000	41,020
Cote D'Ivoire	47,750	36,000	83,750
Gambia	1,670	18,000	19,670
Ghana	13,185	66,000	79,185
Guinea Conakry	15,541	44,000	59,541
Guinea Bissau	5,110	Not available	5,110
Liberia	100	1,000	1,100
Mali	147,643	105,000	252,643
Niger	28,885	70,000	98,885
Nigeria	218,800	1,020,000	1,238,800
Sierra Leone	1,000	4,000	5,000
Senegal	71,400	50,000	121,400
Togo	2,008	5,000	7,008
	622,677	1,494,000	2,116,677
% of total	29.4%	70.6%	100.0%

*Estimates are for 2000 to 2005.

Source: Doll and Siebert (1999), Bric et, al. (2010) and FAO/IWMI (2010) for formal systems and Dittoh (1997) and Dittoh et. al. (2010) for informal systems.

The overall Indian experience indicates that there is a need for a well regulated system to avoid over-exploitation of groundwater and a well-organized groundwater monitoring system.

Any fall in watertable would have social implications on differential access to groundwater and distributional issues, as well as the household and community level food security issues. Another problem with the Fadama programme is the increasing conflict situations that arise between different users. That is however not unexpected because multiple-use of common resources by different user groups often result in some conflict.

A new development in West Africa that is going to affect irrigated agriculture is the "land grab" phenomenon. A well-known one is the Malibya project established by the Libyan

Africa Investment Portfolio. Libya has acquired about 100,000 hectares of fertile land in the Office du Niger area for the cultivation of rice and cattle rearing. The concern in general on the “land grab” issue is the extent to which the projects will benefit the people in terms of food security, income, and employment (Cotula et. al. 2009). For the Malibya project in particular, there is a concern for the possible misuse of water. According to the Oakland Institute (2011) the irrigation capacity will be about 4 billion cubic meters per year. That raises a serious concern for water use in the sub-region because it is known that water level has dropped by 30% in the Office du Niger area within the last three decades. Also, the Malibya project may lead to displacements of tens of thousands of smallholder vegetable producers in the Segou Region of Mali, due to a shortage of both irrigated land and water and affecting livelihoods of many smallholding vegetable farmers. It is not clear how the project would contribute to reducing food insecurity and unemployment in Mali in particular and the sub-region as a whole.

4. Vegetable Production in Arid and Semi-Arid West Africa

The arid and semi-arid West Africa has a Sudano-Sahelian climate and that climate is more conducive to horticultural production (than the humid areas of West Africa) from November to March (the dry season) because of higher solar radiation, cooler nights and less pest and disease pressure (Pasternak et al., 2006). The humid areas in the south (or coastal areas), on the other hand, experience cooler weather and high sunshine from March to October and that period is suitable for vegetable production in those areas. There is, thus, potential for trade in vegetables between the north and south of the West African sub-region as well as with other parts of Africa and beyond.

Over 75% of the irrigated area in West Africa is under vegetables since almost all the informal irrigation is for vegetable production and a considerable proportion of the formal small scale irrigation systems are for vegetable production. Vegetables are cultivated mainly because of their high agro-climatic suitability, high value added (income) per unit of land, and high nutritional and medicinal importance. They are however very sensitive to water stress or dry spell in the growing period. They are also easily perishable. Therefore, farmers produce vegetables under high risks in terms of production as well as marketing ─ reflected by high fluctuation of market prices.

Irrigation is the means to reduce the risks in farming, ensure high yields as well as make production possible all year round. That means vegetable production needs to be managed competently; in a business-like manner. Several past studies have demonstrated higher economic profitability of vegetable production, under both rainfed and irrigated conditions, than cereals and other staple crops (Weinburger and Lumpkin, 207; Amisah et. al. 2002; Adewumi et. al., 2005). Also it has been shown that the irrigated vegetable systems are more profitable than rainfed vegetable systems (Dittoh, 1992) and that vegetable markets across Nigeria are quite integrated (Dittoh, 1994). The findings imply that vegetable production is responsive to market forces and prospects for commercialization are high. All these findings point to a very good agribusiness potential of irrigated vegetable production in the West African sub-region.

Many different types of vegetables are cultivated across the sub-region. The main ones include onions, tomatoes, peppers (hot and sweet), several types of melon, eggplants and leafy vegetables (exotic, such as lettuce and cabbage, and local such as kenaf, hibiscus and roselle), green beans and okra. Almost all vegetables produced under irrigation are mainly for the market. However, the indigenous leafy vegetables are also consumed in relatively large quantities by the people and serve as “hunger gap fillers” during crop failures and during the long dry seasons in the arid and semi-arid areas of West Africa (Amisah et. al., 2002).

Vegetables production in the arid and semi-arid parts of West Africa may be categorized into four types as follows:

1 *Rainy season production*: Production is undertaken around family houses (home gardens) by women. Indeed vegetable production is traditionally women’s activity. Mainly indigenous vegetables such as local leafy vegetables, okra, pumpkin and roselle are produced by women in the households mainly for home consumption but some can be sold.

2 *Small-scale production under irrigation*: These are produced using almost all the types of irrigation systems being discussed in this Chapter but particularly along rivers and on small dam sites in relatively rural and remote areas. Mainly onions, tomatoes, pepper and exotic leafy vegetables (cabbages, lettuce and others) are produced for sale in local market.

3 *Urban and peri-urban production*: This production takes place along the banks of rivers and streams running through cities and towns. Deep wells, boreholes and taps are also sources of water for urban and peri-urban small-scale vegetable production. Mainly exotic leafy vegetables are produced for the urban markets; people living in fenced bungalows also cultivate vegetables in home gardens mainly for home consumption. Wastewater and sludge are commonly used for farming around large towns and cities. According to Dreschel et. al. (2006), informal irrigation in the rural-urban interface in Ghana covers an area greater than the area reported under formal irrigation in the whole country. Another study by Kintomo et al. (1997) in Ibadan, Nigeria, reported that it is more profitable to grow vegetables during the dry season in the city (if water is available) because of higher quality of produce than during the rainy season. The main vegetables grown under the urban and peri-urban irrigation system include lettuce, spring onions, spinach, and cabbage. Others include carrots, onions, amaranth, eggplant, tomatoes, okra, hot pepper, green beans, and cucumber. Dreschel et al. (2006) noted that though peri-urban agriculture covers a small percentage of the total irrigated area, it accounts for between 60 and 100 percent of the consumed leafy vegetables in cities like Dakar, Bamako, Accra, Kumasi, and Tamale, depending on crop and season.

4 *Large-scale production for markets in cities and for export*: This production takes place mainly under drip irrigation. The production involves relatively large investments in modern and large-scale drip irrigation equipment. Some of the examples of this kind of production include green beans and sweet pepper in the Niays zone, and other vegetables in the St. Louis area of Senegal; onions and sweet pepper in the Tahoua and Zinder-Diffa regions of Niger respectively; and different types of leafy vegetables in the Bobo Diallouso area of Burkina Faso. There are also large scale, mainly public, gravity irrigation systems in Nigeria (and to some extent

Ghana) but they do not focus on vegetable production as those in Senegal, Niger and Burkina Faso.

Most of the vegetables produced in West Africa are sold and/or consumed without any industrial processing and/or any form of proper packaging. Thus West African vegetable value chains are quite short. The agribusiness potential becomes greater if vegetable value chains are systematically developed, and improved post-harvest management and technologies are introduced. The development of vegetable value chains will result in increased income due to value addition and employment, since several sections of the expanded value chains will employ labour; and the resultant effect will be the increase in food and nutrition security of all actors along the chains.

5. Irrigation, Income Generation, Employment and Food Security

It is clear from the discussion so far that irrigated agriculture has good income generation (poverty reduction), employment and food security enhancing potential and more so in the arid and semi-arid parts of West Africa. The degree of income generation potential of irrigation is however determined greatly by the types of crops grown under irrigation, access to markets and institutional and policy support measures. Vegetable production, as against low-value staple food crops, has high income generation potential mainly because of the relatively higher price and income elasticities of demand for vegetables. Incomes in urban areas are generally on the increase in almost all West African countries due to various factors including greater exploitation of natural resources and increased commerce and services sector growth. The cultivation of vegetables and other crops with similar elasticities can also contribute to reducing rural poverty faster. Increased production of staple crops under market-oriented systems will result in lower incomes because of their low price and income elasticities of demand.

According to Devereux and Maxwell (2001), "food insecurity in Africa is a product of low agricultural production plus low incomes, not one or the other alone". Incomes are important determinants of food security in West Africa mainly because rural farm household are net purchasers of food (World Bank, 2007). Thus, improvements in rural (as well as urban) household incomes will result in significant reductions in food insecurity. With limited off-farm sources of income, incomes from irrigated vegetables are important for food security in households that undertake irrigation. Also, micronutrient malnutrition has been a major public health problem in all West African countries (Lopriorea and Muehlhoff, 2003) and that component of food and nutrition insecurity has often been overlooked. Micronutrient malnutrition is a "silent killer" (Swift and Hamilton, 2003) and the consumption of vegetables and fruits among other foodstuffs is the solution. As stated by Tenkouano (2011) even if Africa is adequately fed by staple crops, it will not be nourished until diets improve; millions of people in sub-Saharan Africa will remain vulnerable to ailments that compromise their mental and physical fitness. Irrigated vegetable production, therefore, has a very high potential for ensuring food and nutrition security in rural farming households as well as in urban areas in West Africa.

Irrigation is very labour-intensive especially in the West African sub-region where mechanized agriculture is minimal and most of the farming operations are manual. Even with drip irrigation where labour requirements are drastically reduced in the process of water lifting (Pasternak et. al., 2006; Oumarou, 2008; Woltering et. al. 2009), crop cultivation still demands intensive labour use. Irrigated vegetable production in particular is labour-intensive from land preparation to harvesting. The marketing of vegetables in local markets is also labour-intensive. That means the development of irrigated vegetable production substantially increases the employment of labour, even skilled labour, because of high profitability that is associated with it. Irrigated vegetable production is a potential solution to the growing graduate unemployment problem in West African countries by engaging them as "agri-prenures" for modern vegetable production systems. Increase in employment also enhances food security since it implies income generation through wage income and/or production.

6. "AFFORDABLE" MICRO IRRIGATION FOR VEGETABLES SYSTEMS IN WEST AFRICA

Generally 'micro-irrigation' refers to drip, trickle, spray, micro-jets or mini-sprinkler systems designed to use available water more efficiently (Belder et. al. 2007). In this paper however micro-irrigation includes small scale local irrigation typologies involving the use of buckets and watering cans as well as manual devices including treadle pumps and small motor pumps. Affordable micro-irrigation for vegetables (AMIV) systems refer to irrigation systems which smallholder irrigators are using currently and those they are aspiring to obtain in the near future. Farmers' aspirations for better irrigation technologies are not based on wishful thinking; but are based on their farm investment decisions, as illustrated by the surveyed farmers across the countries. The success of the National Fadama Development Project (NFDP) in Nigeria can be attributed to smallholders' eagerness to invest in profitable new technologies. Farmers will always invest in irrigation technologies that are profitable and also within their reach; that is, affordable ones.

Major typologies of AMIV technologies that are common in the arid and semi-arid areas of West Africa are as given in Table 2. Several variants of the systems are lumped to form each of the typologies. The first typology for example can be as rudimentary as using a gourd to fetch from a small dam to irrigate a few beds and it can be as advanced as fetching into "California reservoirs" to irrigate by gravity. Costs and returns calculations were therefore carried out for specific types in specific locations to indicate each of the typologies. A summary of the costs, the payback period, and the net annual returns for the AMIV typologies are as given in Table 3.

From Table 2, it is obvious that irrigators' preferred typology is lifting groundwater with a motor pump followed by lifting surface water using a motor pump. The use of the motor pump thus seems critical for development of irrigation in the arid and semi-arid areas of West Africa. The profitability in the use of the motor pump as indicated in Table 3 is however not conclusive. While its use in Senegal is the most profitable, negative returns are indicated in the case of Mali. That indicates that profitability of AMIV systems cannot be generalized for a large geographical area; it varies by countries and even by sites. The assessment of profitability of irrigated agriculture involves many factors and they all need to be considered.

The use of complementary inputs, the prevailing product prices and several other factors also affect profitability of a particular irrigation technology. Also, differences in prevailing socio-economic conditions in various countries affect profitability. Farmers indicated that the high price of fuel is their major constraint in the use of motor pumps; fuel prices greatly vary across the countries.

Table 2 also indicates farmers preference to move away from the bucket/watering can/calabash technology, even though returns from this technology is not much lower than others. It is because the bucket/watering can/calabash technology can only cover a small plot of crop land, and it is a drudgery task; thus the income obtainable from its use per household is very low. Across the small plot areas, the return from bucket watering, on per unit area basis, is however comparable with other technologies (Table 3) – although it does not fully account for the additional labor input that goes into the irrigation.

The use of electricity in irrigated agriculture was yet to be popular at the surveyed sites. Among the surveyed sites, it was only in Senegal where it was commonly used. Farmers reported that electric pumps are cheaper and the running costs for irrigation are much lower compared to diesel or petrol pumps. However, except in Senegal, access to electricity was the major bottleneck in most of the surveyed sites.

Table 2. Typologies of Common Affordable Micro Irrigation for Vegetables Technologies in West Africa

Name of Irrigated System*	Source of water	Mode of water conveyance	Irrigators' composite ranking of systems (1=best)	Main Challenges of Irrigation Systems
1. Permanent well/ Boreholes/Tubewells, Motorized pump System	Permanent wells, boreholes, and/or tubewells	Motorized pump and gravity	1	A relative expensive system but preferred.
2. Surface water, Motorized pump Basin System (individuals) (includes aspects Fadama Systems)	River, streams and dams	Petrol or Diesel motorized pumps (and gravity)	2	It is an expensive system. Fuel cost is high
3. Surface water, Motorized pump Basin System (Communal or group) (includes aspects of Fadama Systems)	Rivers, streams and dams	Petrol or Diesel motorized pumps (and gravity)	3	It is an expensive system. Fuel cost is high
4. Permanent well, Watering can/Bucket Fetch System	Permanent Wells	Watering cans and/or buckets	4	Water lifting is laborious
5. Shallow well, Watering can/Bucket Fetch System (includes aspects of Fadama Systems)	Shallow wells	Watering cans, buckets, gourds	5	Temporary nature of wells and tedium of lifting water
6. Surface water, Watering can/Bucket Fetch System	Rivers, streams, dams and dugouts	Watering cans, buckets, gourds	6	Water lifting is tedious

*There are often several variants of the various categories identified here. Thus within a particular system the profitability and prospects for sustainability can vary very widely.

Source: Field Survey, November/December 2009.

Table 3. Investment Costs and Net Annual Returns (Profits) (in US$) for Affordable Micro Irrigation for Vegetables Systems per 0.05 hectares (500m^2)

Name of Irrigated System	Specific cases used as examples for profitability analysis	Investment costs (in US$)	Payback period (in years)	Net annual return (in US$)
1. Permanent well/ Boreholes/Tubewells, Motorized pump System	Balayere, Niger	618.91	3.94	33.28
	Ndiar, Senegal	675.43	1.00	540.46
2. Surface water, Motorized pump Basin System (individual)	River Niger in Segou, Mali	266.74	6.01	-9.00
3. Surface water, Motorized pump Basin System (Communal or group)	Korania, Upper East Region, Ghana	385.00	1.17	253.00
4. Permanent well, Watering can/Bucket Fetch System	Niessega, Burkina Faso	426.74	1.42	215.20
	Balayere, Niger	299.57	1.20	189.00
5. Shallow well, Watering can/Bucket Fetch System	Zangum, Northern Region, Ghana	47.00	0.16	281.50
6. Surface water, Watering can/Bucket Fetch System	River Niger in Segou, Mali	92.82	0.63	128.83

Source: Field Survey, November/December 2009.

Each of the categories of AMIV technology listed in Table 2 has some advantages as well as challenges. They can all, however, be improved upon for specific needs and requirements of the irrigation community members in each of the sub-region. The improvements must aim at affordability of the technologies, lower-costs per unit of vegetable production, and higher productivity (crop yields or returns).

For increased food security, higher incomes and greater employment opportunities, farmers' access to diversified affordable irrigation technologies, in the sub-region, needs to be enhanced.

7. Potential Affordable Micro Irrigation for Vegetables Systems in West Africa

Drip irrigation technologies have been developed as improvements upon some of the AMIV technologies noted earlier. They are mainly aimed at smallholder irrigators in dry regions. They are being referred to here as 'Potential AMIV' (PAMIV) technologies to make a point that they are relatively expensive to average farmers in the sub-region and may not be affordable by majority of the smallholder irrigators. There is a need to develop smallholder irrigation governance systems (arrangements) to ensure that smallholding farmers who desire to use them can get access to these technologies. Major typologies of the types of drip irrigation systems that were encountered in Burkina Faso, Ghana, Mali, Niger and Senegal during the 2009 survey are presented in Table 4. A summary of the investment costs, the payback period and the net annual returns of the first eight typologies described in Table 4 is also presented in Table 5. It is obvious that returns from the system that uses motor pumps to lift groundwater are higher than those from the other technologies.

Drip irrigation is preferred by farmers in all the sites surveyed because of better water control and higher productivity under the systems. The combined investments on motor pumps, permanent wells or boreholes, concrete reservoirs as well as drip irrigation equipment are however beyond the capabilities of most of smallholder irrigators. The investment cost required for installing drip for 500 meters square of crop land (0.05 hectares) (with manual pumps as means of conveyance and simple barrels as reservoirs -Table 5), is a minimum of about US$470 for each irrigator. It is worth noting that smallholder irrigators have largely rejected the use of manual pumps in the study area mainly because of the tiresomeness in its use.

Table 4. Potential Affordable Micro Irrigation for Vegetables Systems in West Africa (Drip irrigation systems)

Drip Irrigation (Potential AMIV) System	Source of water	Mode of water conveyance	Type of reservoir	Users	Examples of systems locations in the West African sub-region
1. Dam to Barrel/Gravity	Dam	Gravity (through pipes)	Barrels	Group	Binduri and Golinga (Ghana)
2. River or Dam to Concrete reservoir /Motor pump	River or Dam	Motorized pump	Concrete reservoir	Individual or Group	Diakoro and Nerekoro (Mali)
3. River or Dam to Barrels/Bucket fetch	River or Dam	Bucket fetch	Barrels	Individual	Tono (Ghana)
4. Well to Barrels/ Bucket fetch	Permanent well	Bucket fetch	Barrels	Individual	Niessiga (B/Faso); Tinga (Mali)
5. Well to Barrels /Manual pump	Permanent Well	Manual pump	Barrels	Individual	Kuntiasso (Mali); Tintolu (B/Faso)
6. Well or Borehole to Concrete Reservoir/Motor pump	Permanent Well/ borehole	Motorized pump	Concrete reservoir	Individual or Group	Kolo, Birnin (Niger); Ouahigouya, Zom, Koumbri, Ladre (B/Faso)
7. Well or Borehole to Barrels/Motor pump	Permanent Well/ borehole	Motorized pump	Barrels	Individual or group	Ngoha Ndioffogor (Senegal); Kuer Yaba Diop (Senegal)
8. Pipe to Barrels	Pipe (Town water system)	Pipe	Barrels	Individual	Ouahigouya (B/Faso), Kayes (Mali), Univ. Diop (Senegal)
9. Well or Borehole to Barrels/Electric pump	Permanent Well/ borehole	Electric pump (into overhead tank)	Barrels	Individual or group	Kuer Yaba Diop (Senegal)
10. Mechanized borehole to Concrete reservoir/ Solar or motor pump	Mechanized borehole	Solar or motorized pump	Concrete reservoir	Group	Tanka and Winditan (Niger)
11. Mechanized borehole to Overhead tank/ Electric pump and gravity	Mechanized borehole	Electric pump (to overhead tank) and gravity	Overhead tank and barrels	Group	Kuer Yaba Diop and Bissao (Senegal)

Source: Field Survey, November/December 2009.

Table 5 shows that all the major typologies of irrigation across the sites (countries) are profitable; the most profitable being the use of piped water with motor pumps in Senegal. Nevertheless, pipe supplied water, as practiced in Senegal, cannot be an option for irrigation except in the case of home garden cultivation.

The costs and returns analysis in Table 5 is only indicative because, as stated earlier, profitability of irrigated agriculture across different countries with different input and output pricing regimes cannot be generalized. What is relevant is that, from the farmers' perspectives, all the technologies are profitable and with relatively short payback periods.

Table 5. Investment Costs and Net Annual Returns (Profits) (in US$) for Potential AMIV Systems per 0.05 hectares (500m^2)

Name of Irrigated System	Specific cases used as examples for profitability analysis	Investment costs (in US$)	Payback period	Net annual return (in US$)
1. Dam to Barrel/Gravity	Binduri and Golinga (Ghana)	620.71	1.16	409.43
2. River or Dam to Concrete reservoir /Motor pump	Diakoro and Nerekoro (Mali)	929.78	3.85	55.57
3. River or Dam to Barrels/Bucket fetch	Tono (Ghana)	625.00	1.43	312.14
4. Well to Barrels/Bucket fetch	Niessega, B/Faso	820.43	1.29	469.61
	Tinga, Mali	879.78	4.49	20.13
5. Well to Barrels /Manual pump	Kuntiasso (Mali)	468.91	2.05	134.48
6. Well to Concrete reservoir/Motor pump	Kolo, Birnin (Niger);	1627.00	2.88	240.24
	Zom, Koumbri, Ladre (B/Faso)	1693.48	2.03	494.73
7. Borehole to Barrels/Motor pump	Ngoha Ndioffogor and Kuer Yaba Diop (Senegal).	1540.65	1.17	1010.13
8. Pipe to Barrels	Univ. Diop (Senegal)	1540.65	1.09	1107.96

Source: Field Survey, November/December 2009.

This has implications for funding options. Irrigated vegetable production especially using the PAMIV systems is good investment opportunity for even rural commercial banks and other rural financial institutions.

Governments, especially provincial and district governments, can partner with the private sector and vegetable farmers to support this kind of agribusiness sector development with better access to irrigation water. It is even known that the use of electric pump to lift both surface and groundwater for irrigation is much cheaper (Nanes, 2011). It is being considered as the future choice for irrigation in the sub-region.

8. "GROWTH PATHS" FOR IRRIGATED VEGETABLE PRODUCTION IN WEST AFRICA

The AMIV technologies are clearly important for the development of irrigated agriculture in West Africa. Modest profits are made using them but if the systems are improved upon and/or drip irrigation technologies are embraced, smallholder farmers are likely to increase their income substantially.

Over and above the technical improvements in technologies are organizational improvements in the production, marketing, processing and consumption of vegetables in the West African sub-region. Vegetable value chains should be developed along "growth paths" to ensure efficiency and sustainability of the vegetable production-marketing-processing-consumption nexus. Pursuance of vegetable growth paths with smallholder farmers as core producers will ensure systematic emphasis on wealth creation by poor farmers, employment opportunities in rural and urban areas and food and nutrition security with gender inclusion.

The following vegetable growth paths, which are not necessarily mutually exclusive, may be identified:

1. Specialized irrigated vegetable production for export.
2. Commercialization of indigenous vegetables through their production under irrigation
3. Irrigated vegetable-livestock integration systems
4. Urban and peri-urban vegetable production
5. Organic vegetable production

These vegetables growth paths could be for only exotic vegetables, only indigenous vegetables or both in mix settings across the countries. The five types of vegetable systems and their linkages to income generation, employment and food security issues are elaborated below.

1. Specialized Irrigated Vegetable Production for Export

A number of tropical vegetables such as green beans have considerable demand in Europe and North America. There is also demand for such vegetables in the urban areas in the West African sub-region. The present trend is for big time foreign investors to acquire large irrigated areas to produce such crops. There is however still a place for smallholder producers to participate in the process either as out-growers or as farmer groups with the ability to bulk their produce for export. The promotion of the group farmer model in the context of Public Private Partnership (PPP) is a good growth path for the West African sub-region. The model refers to the groups of farmers, with government or NGO support, investing in irrigation equipment and related infrastructure. The employment and income distribution potential of that model is very high and it is likely to be largely sustainable. The model can be feasible only in the context of PPP because the investment requirements are very high. The model is being tried in the Thies and Fatick Regions of Senegal with the assistance of non-governmental organizations and an Isreali government-supported project.

The model involves group ownership of boreholes and/or deep wells as well as water pumps and overhead tanks (if found necessary and feasible). Production is however by individuals or family units. The marketing of the produce could be by private packaging and marketing firms or by the farmer groups themselves. That clearly establishes a good vegetable supply chain with support from the irrigation development project, with all the advantages and better market linkages. It must be noted that the processing of vegetables for both export and the local market requires substantial use of water and that has to be factored into the investment decisions with regards to this model.

2. Commercialization of Indigenous Vegetables through Production under Irrigation

Indigenous vegetables are known to contain considerable amounts of vitamin A and other nutrients, much higher than exotic vegetables. Their production is already being undertaken by women in almost all farming households in the arid and semi-arid areas under rainfed conditions. Production under irrigation is also now becoming considerable because of the growing demand in urban areas. Demand can be improved further if packaging and marketing is improved upon. Therein also rests the agribusiness potential and thus, the income generation potential, of indigenous vegetables. With improved packaging and marketing the vegetables can be transported to more distant urban areas. The gender dimension of this growth path cannot be overlooked. Improvements in indigenous vegetable production should benefit women largely because they have the indigenous knowhow and can cultivate and market the vegetables better.

There is also a need for the general public to be made aware of the nutritional importance of indigenous vegetables to increase the demand for them in and outside production areas. It is known that indigenous (or traditional African) vegetables are rich in micronutrients and antioxidants (Yang and Keding, 2009; Keatinge et. al. 2011) and contain other health-related phytochemicals (Erasto et al. 2004). It is also believed the increase in micronutrient deficiencies in parts of the West African sub-region has been due to decreased consumption of indigenous vegetables and semi-wild fruits (Dittoh, 2003). Complete food and nutrition security in West Africa seems to be critically dependent in recognizing the role of indigenous vegetables in the diets of the people and developing their value chains effectively.

Formalizing the production of indigenous vegetables under irrigation is the way of assuring urban dwellers, restaurants and the several food "joints" in urban areas of assured supplies of these vegetables in the wet and dry seasons. Private agribusiness should be promoted to handle the marketing of the indigenous vegetables. The irrigators should concentrate on production but be assured of a market and good return on investment. The employment potential of the vegetable growth path is evident.

3. Irrigated Vegetable-Livestock Integration Systems

Multiple use of irrigation water is the rule in all parts of the world. It ensures to a large degree efficiency of water use. Livestock is very important in the arid and semi-arid areas of West Africa and every livestock farmer in the area will insist that the two most important constraints to livestock rearing in the area are water and feed. Irrigated vegetable-livestock integration ensures that livestock get both adequate water and some supplementary feed. Vegetables that cannot be sold due to post-harvest loses, deterioration of quality, dumping, or for any other reasons can be fed to livestock particularly small ruminants. The manure of the animals in turn is important as a complementary input in irrigated vegetable production. The limited response of some crops to inorganic fertilizers is due to the very low organic matter content of the soils (IFDC, 2006). The income generation potential of multiple use of water is tremendous. According to Ayariga (2011), irrigated agriculture's profitability potential is in the multi-functional use of irrigated water and that is being amply demonstrated in parts of the Northern and Upper Regions of Ghana. The water, animal feed and animal manure are efficiently utilized to enhance profit. Labour is equally used efficiently in producing the vegetables and livestock. Food and nutrition security is also enhanced in terms of adequacy in quality. It will not be only micronutrients that will be produced, through the vegetables, but protein (a macronutrient) through the animals and possibly fish.

4. Promotion of Urban and Peri-Urban Vegetable Production

Urbanization in West Africa is taking place at quite a fast rate and many city authorities are getting overwhelmed with unemployment, underemployment and related social problems. Urban poverty and unemployment is growing and urban and peri-urban irrigated vegetable production is a major source of employment and wealth creation for many unemployed youth in urban areas. It is also a good source of safety nets for landless and urban poor in times of economic down turn in the urban centers. Most African cities have no green belts. Indeed many fertile lands within cities have been sold out for residential and other buildings. However that aspect of urban development can be corrected given the very positive agribusiness potential of urban and peri-urban vegetable production. Demand for vegetables produced in urban and peri-urban areas is very high. They tend to be cheaper than vegetables brought in from elsewhere because transportation and other transactions costs are much lower.

The urban and peri-urban vegetable production growth path is relatively easy to develop since the private sector can be easily convinced to join the government in a public-private partnership arrangement. The demand is assured, transactions costs are minimal, profits tend to be relatively high and thus it is a lucrative agribusiness enterprise. Modern and relatively expensive drip irrigation can be invested in this kind of venture because the investment can be recouped within a relatively short period of time. A major challenge that has been encountered in several cases is conflicts with urban land developers (for residential purposes) and town and city authorities.

5. Promotion of Organic Vegetable Production

The production of organic vegetables by irrigation is another growth path worth developing. There is a premium price for organic vegetables especially by the much richer folks in cities and towns. This could therefore be a stand-alone growth path or as a component of the urban/peri-urban irrigated vegetable growth path. Organic production is a relatively specialized area of production because of the need to meet certain "organic standards". Thus, it is educated and well-informed smallholder irrigators that can more conveniently undertake organic vegetable production with assured high levels of profitability. As a specialized area of production, people with the specific specialization or skill will be employed. It will also enhance food and nutrition security in the sense that the growth path will provide quality, safe and healthy food for the people. It also has a high export potential since there is considerable demand in developed countries for organic vegetables.

9. CONDITIONS THAT CAN LEVERAGE IRRIGATED VEGETABLE GROWTH PATHS AND MAJOR CHALLENGES

The use of pumps will be predominant in all the growth paths. Farmers have clearly indicated that manual pumps are too tedious and even have preference of use of watering cans over manual pumps. Diesel and petrol pumps are acceptable and are commonly available. With respect to electric pumps, some farmers in the sub-region are not even aware that electric pumps can be used for irrigation. In any case there is no electricity where most of the farms are currently. As stated earlier, however, electric pumps are the most efficient for irrigated vegetable production; the pumps are cheaper, are of very different sizes to choose from and electricity charges are much lower in all countries compared to the cost of diesel or petrol. Countries in the arid and semi-arid areas of West Africa are thus being encouraged to supply electricity to irrigated areas for the purpose of promoting these growth paths.

Groundwater use is likely to dominate in the growth paths discussed above. Farmers have indicated great preference for groundwater use because of convenience as well as easy control and greater efficiency of use. Giordano (2009) has indeed pointed out that "there has been an amazing, if largely ignored, boom in agricultural groundwater use that has provided improved livelihoods and food security to billions of farmers and consumers". There are however serious challenges to groundwater use for agriculture as noted earlier in the Chapter. There is a need for extensive assessment of groundwater resources for effective groundwater use planning. Farmers should also have access to information on the implications of groundwater lifting and there must be good monitoring of groundwater recharge and water levels to prevent overexploitation.

Complementary roles of governments and the private sector are very important in enhancing the growth paths; thus, all the paths have various degrees of Public-Private Partnership implications. While governments will provide good enabling environments in terms of infrastructure and possibly use its stabilization policy instruments to ensure adequate credit provision and market opportunities, the private sector will see to the efficient functioning of the various vegetable value chains.

Without research, particularly action research, the "growth paths" are unlikely to be exploitable. It is necessary that "agribusiness incubators" be established and multi-disciplinary research teams can work through them to promote innovative agribusiness initiatives. Agribusinesses must grow out of the growth paths for their sustainable existence.

The threat to all the growth paths is the possibility of overproduction and subsequent market glut of perishable products such as vegetables. All the growth paths have to depend on well informed market analysis and market information. The development of information and communication technology (ICT) to benefit agriculture and the rural areas within West Africa will greatly enhance access to market information. A more formal approach to avoiding or reducing the glut is also exploring options for contract farming. Contract agreements have to be negotiated between producers and agribusinesses as well as market intermediaries and consumers (for example supermarkets, restaurants etc.) to forestall serious glut problems. Another way out of market glut is the possibility of processing vegetables for the market. Simple farm level processing can add value to vegetables produced, so will bigger processing units that process the produce of several farmers and farmer groups. It must be pointed out, however, that processing at all levels require substantial amounts of clean water and that has to be explicitly planned for in these commercially oriented growth paths.

CONCLUSION

This Chapter outlined the need and the potential that exists for irrigated vegetable production in the arid and semi-arid areas of the West African sub-region. The employment, income generation and food and nutrition security potential of irrigated vegetable production is clearly high. Irrigated vegetable production, in various countries, by smallholder farmers, is clearly a viable development path for the arid and semi-arid zones of West Africa. What is required is a focus on growth paths that will translate the potential into reality. A number of growth paths were outlined. They are not mutually exclusive and can be conveniently combined to ensure feasible agribusiness enterprises and value chains that can be improved upon over time. The suggested growth paths aim at taking advantage of specific supply and demand situations (for specific vegetables or groups of vegetables), as well as certain characteristics in value chains that are specific to those growth paths. By focusing on specific growth paths, dynamic and functional value chains can be developed for various vegetables or group of vegetables. Conscious efforts have to be made by all stakeholders particularly governments and smallholder irrigators with support from financial institutions and non-governmental organizations to develop these vegetable cultivation and value-addition growth paths for enhancing food security across West Africa.

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