AgWater Solutions Project
Case Study

Adoption of water lifting technologies for agricultural production in Ghana: implications for investments in smallholder irrigation systems

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The AWM Project
The AgWater Solutions project was implemented in five countries in Africa and two states in India between 2008 and 2012. The objective of the project was to identify investment options and opportunities in agricultural water management with the greatest potential to improve incomes and food security for poor farmers, and to develop tools and recommendations for stakeholders in the sector including policymakers, investors, NGOs and small-scale farmers.

The leading implementing institutions were the International Water Management Institute (IWMI), the Stockholm Environment Institute (SEI), the Food and Agriculture Organization of the United Nations (FAO), the International Food Policy Research Institute (IFPRI), International Development Enterprises (iDE) and CH2MHill.

For more information on the project or detailed reports please visit the project website http://awm-solutions.iwmi.org/home-page.aspx.

Disclaimers

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Summary
Irrigation has become one of the priority development agenda items in Ghana and in Sub-Saharan Africa, in general. There is a genuine endeavor to increase public and large scale private investment in the sector. The on-going smallholder-driven private irrigation development that is largely based on water lifting technologies is not yet fully appreciated. The major premise of this paper is that smallholders themselves can play a significant role in materializing national irrigation development plans, provided they have access water lifting technologies, especially small motorized pumps. In line with this, the paper analyses the adoption pattern and constraints of water lifting technologies in Ghana and suggests interventions that would enhance wider dissemination. Currently, these technologies are mainly accessible to better-off farmers. The main factors inhibiting wider application are poorly developed supply chains, lack of access to finances, high operational and maintenance costs, high output price risks, and lack of institutional support. To realize the potential of water lifting technologies, improvements are required in the entire value chain of lift irrigation systems.

1. Introduction

There is a renewed emphasis on irrigation development in Ghana and in SSA. The new policy direction seems to favor gravity based surface irrigation or centrally managed large pumps. Lift irrigation systems are based on technologies widely varying in their sophistication from rope-and-buckets for irrigating small plots, to 1000 HP pumps that are operated centrally and irrigate thousands of hectares. It is claimed that lift irrigation systems are the dominant type of irrigation in Ghana and in West Africa due to the proliferation of relatively cheap small motorized pumps from a variety of sources (Abric et al., 2011; Pukey and Vermillion, 1995). Smallholder-driven lift irrigation systems, particularly those based on less than 10 HP pumps, are often ignored in the mainstream irrigation development policy agenda.

The adoption pattern and extent of area under lift irrigation system is rarely documented (i.e., there are no statistics on small private irrigation) and the dynamics of adoption of these technologies are poorly understood. This paper provides information required for charting an irrigation development strategy and prioritizing investments for small-scale, individual irrigators. While the study was conducted in Ghana, the results have Sub-Saharan Africa wide implications. The paper provides answers to the following research questions:

- To what extent are these technologies in use in Ghana?
- What is the current rate and pattern of adoption of water lifting technologies in Ghana?
- What are the reasons for adoption or non-adoption?
- Who are the current adopters? Are they the better-off farmers?

The paper further suggests strategic and policy recommendations with the intent of enhancing wider uptake of water lifting technologies in Ghana in particular and in SSA in general.

2. Methodology, Data, and the Study Locations

Two types of surveys were conducted. First, a census survey was conducted in five regions, where the adoption of water lifting technologies was known to be happening. The five regions were Ashanti, Greater Accra, Volta, Upper West and Upper East (Figure 1). Second, detailed sample surveys were conducted in three regions (Volta, Accra and Ashanti) using the results of the census survey as a sampling frame (Figure 1).

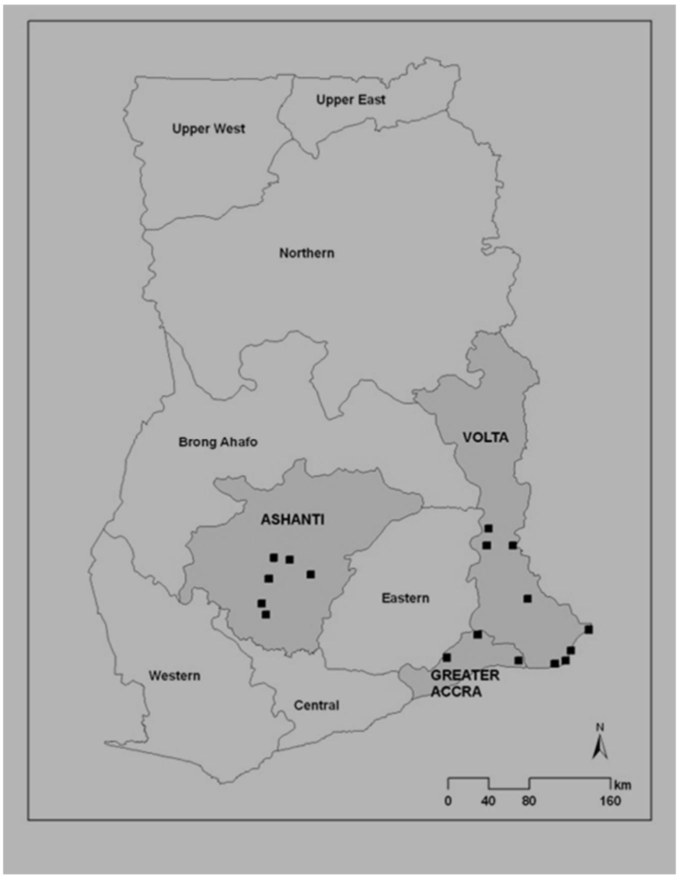


Figure 1. The study locations

2.1 Census survey in selected communities

The five regions (Volta, Greater Accra, Ashanti, Upper West, and Upper East) represent the southern and coastal zones, the semi-deciduous forest, transitional, and the savanna agro-ecological zones. From these regions, a total 20 districts and 68 communities were selected based on the prevalence of water lifting technologies. Subsequently, a hut-to-hut survey was conducted using a structured survey questionnaire in 12,620 farm households.

2.2 The sample survey

The data obtained from the census survey served as a sampling frame in the subsequent in-depth sample survey in Ashanti, Greater Accra, and Volta regions. Nineteen communities, 8 each representing rural and per-urban settlements, and 3 representing urban settlements were selected. A total of 494 farmers were randomly selected using a multi-stage stratified sampling design. Cochran's sample size determination formula for categorical data was used to determine the sample size (Cochran, 1977).

2.3 Typology of farmers and analytical methods

In the analysis of the data, farmers were characterized according to the type of water lifting technologies they commonly use.

- Rain dependent: farmers who depend entirely on rain for agricultural production;
- Bucket users: farmers who lift water with buckets;
- Treadle pump users: farmers who lift water with treadle pumps;
- Petrol or diesel pump users: farmers who lift water with petrol or diesel engine pumps;
- Electricity pump users: farmers using electricity powered pumps to lift water;
- Canal dependent: farmers who depend on canal water for agricultural production, and
- Farmers who use a combination of irrigation types.

It should be noted that irrigation practicing farmers may also have rain-fed plots. As a rule small farmers specializing in irrigated farming alone are rare in Africa. One of the main intents of this paper is to analyze the 'depth' of poverty outreach of water lifting technologies. In other words, who are the current adopters? Are they the better-off farmers? To answer these questions, a composite multi-dimensional poverty index (MPI) was developed using principal component analysis. This index was used to categorize the sample farmers into quintiles (i.e., very poor, poor, middle, rich, and very rich). First, the rain-fed dependent farmers were ranked based on their relative MPI to create the five poverty groupings described above. This approach was used because rain-fed dependent farmers are considered to represent an unbiased sample of the general farming population in Ghana. Cutoff values for the quintiles of these rain-fed dependent farmers were determined and used to group water lifting technology adopters.

Poverty outreach was assessed by constructing bar graphs of the distributions of the water lifting technology adopters and non-adopters (i.e., rain-fed dependent farmers) samples by MPI quintiles and visually inspecting the distribution patterns. By default, the bars for rain-fed dependent farmers are expected to be equal in size across the MPI groups and, if water lifting technologies are poverty neutral, the distribution of adopters is expected to follow a similar pattern to that of entirely rain-fed dependent farmers.

3. Results and Discussion

3.1 Socio-economic and demographic characteristics of the sample farmers-a comparative analysis

Water lifting technology adopters tend to be younger and predominantly male, with a high child dependency ratio and lower age-dependency ratio. The dependency ratio is an age-population ratio of those not economically active (the dependents) and those in the labor force (the productive people). The dependents usually include those under the age of 15 and over the age of 64. The productive people make up the population between ages 15-64. The dependency ratio can be decomposed into the child dependency ratio and the age dependency ratio. As the ratio increases there may be an increased burden on the productive part of the population to maintain the welfare of the economically dependent.

Taking the proportion of women in the rain-fed dependent sample as a bench mark, we can conclude that women are under-represented in the water lifting technology adopters' sample, but over-represented in the canal dependent farmers sample (Table 1). Currently, male headed households had significantly better opportunities for adopting water lifting technologies. The higher proportion of female headed households in the canal irrigation sample may be due to deliberate targeting of women farmers in irrigated land allocation in the public schemes.

Table 1. Gender disaggregation of households

Farmer typology	Male headed households	Female headed households	N
Rain-fed dependent	76.2	23.8	84
Bucket users	88.2	11.7	222
Petrol/diesel pump users	86.5	13.5	104
Electric pump users	94.5	5.1	78
Canal dependent farmers	77.4	22.6	31

Water lifting technology adopters tend to have a better level of education. This is particularly so for electric pump users; about 30.8% of which had college or university level training. The proportion of illiterate farmers in the rain-fed dependent category is higher (Table 2).

Table 2. Levels of education of farmers adopting different water lifting technologies

Farmer typology	Illiterate	Primary	Junior Secondary School	Senior Secondary School	O Level	A level	College	University	N
Rain-fed dependent	18.1	15.7	39.8	24.1	0.0	0.0	2.4	0.0	83
Bucket users	13.6	17.7	38.2	13.2	2.3	2.3	10.5	2.3	220
Petrol/diesel pump users	10.6	22.1	37.5	20.2	2.9	1.9	4.8	0.0	104
Electric pump users	3.9	6.4	42.6	10.3	3.9	1.3	24.4	6.4	78
Canal dependent	9.7	22.6	41.9	9.7	6.5	3.2	6.4	0.0	31

Farmers practice diverse livelihood strategies (Table 3). Arable crop farming and non-farm activities are the major occupations of the sample farmers. The importance of non-farm activities in the overall livelihood strategies of the sample farmers is remarkably high.

Table 3. The occupational profile of economically active household members (%)

Activities	Rain-fed dependent	Buckets users	Petrol Pump users	Electric Pump users	Canals dependent
Arable crop farming	53.3	51.1	55.5	49.8	50.0
Tree crop farming	6.1	1.2	0.3	0.0	0.0
Livestock farming	0.9	1.2	0.3	0.4	1.0
Salaried workers	4.2	10.6	8.5	18.0	9.2
Non-farm activities [a]	33.2	31.2	31.2	31.4	38.8
Fishing	2.3	4.7	4.1	0.4	1.0
N	214	679	317	255	98

[a] Non-farm activities include: bricklayer, carpenter, tailor, Artisans, building contractor, matron, hair dresser, driver, seamstress, mechanic, petty trader, engineer, pastor, crop marketing, crop processing, etc.

There are some differences in the occupational profile of the farmers. Proportionately more household members from rain-fed dependent farmers are engaged in tree-crop farming. Significantly higher proportions of water lifting technology adopters are engaged in salaried employment. This is particularly so for farm household members who use electric pumps. The occupational patterns of the sample farmers from the three regions are generally similar. Farmers in Greater Accra region derive their livelihoods from occupations other than farming.

3.2 Access to land and water resources

Access to water source and suitable land influence the probability of adopting water lifting technologies. The major water sources used by lift irrigation technology users are rivers (30.9%), groundwater (30.6%), streams (19.3%), dugouts (14.9%), small reservoirs (2.2%), and lakes (2.1%). Except in the Volta region, farmers who depend entirely on rain-fed agriculture have also reported to have access to surface water sources such as rivers, streams, and dugouts. Only 16.3% of the farmers who are entirely rain-fed dependent reported to have no access to a water source. Thus, access to water may not be a major limiting factor for adopting water lifting technologies. There was some difference in the type of water sources accessed by the different categories of farmers. About 95% of the electric pump users depend on groundwater sources. Thus, farmers using electric pumps for lifting water rely almost exclusively on groundwater sources. Farmers using buckets and petrol/diesel pumps for lifting water have access to range of water sources indicating the versatility of these technologies.

However, the mere availability of a water source is not enough. It has to be within an acceptable distance from the settlement. For those who have reported access, it is often available within a maximum distance of a kilometer (Figure 2). As expected, the farmers rate groundwater highly with respect to the reliability of access and availability followed by rivers.

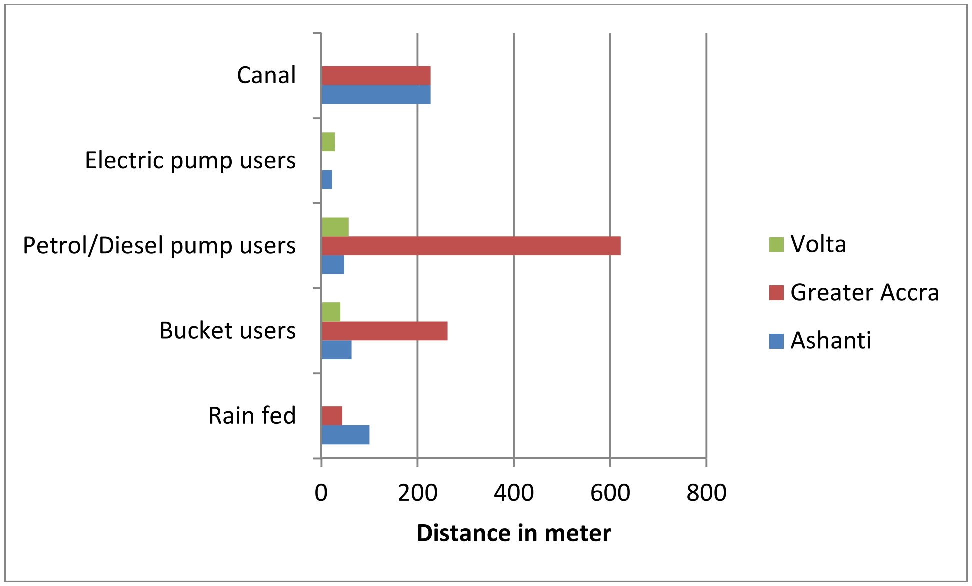


Figure 2. Distance in meters, of water lifting technology adopters from farms to water sources

The perception of farmers' water rights or water use rights also influences the farmers' decision to invest. The majority of the respondents (more than 77%) consider the water sources as their own. Therefore, they claim that they can use water, especially groundwater, without obtaining permission from any authorities. About 13% of the farmers with access to small reservoirs and dugouts reported that they needed to have permission from the chief or other relevant authorities to use water. The perception of the farmers regarding water use rights is divergent from official policies, which states that water resources in Ghana belong to the state.

To invest in water lifting technology, farmers also need suitable land in addition to water. About 88.1% of the sample households reported that they had potential irrigable areas. However, only 48% of the households that claimed to have potential irrigable area, have fully used their land. This value varies from region to region. In Ashanti, 26.7% of the households with potential irrigable land have fully developed their land. The corresponding values for Greater Accra and Volta regions were 61.6% and 48.6%, respectively. Alternatively, 52% of the sample farmers with potential irrigable area have unutilized irrigable area. The mean potential irrigable area is about 1.44 ha (Table 4). The highest mean potential irrigable area was reported from Volta (1.77 ha), while the lowest recorded was for Ashanti (1.14 ha). Mean potential irrigable area for Greater Accra was 1.49 ha.

Table 4. Cultivable area and potential irrigable area

Farmer typology	Own farm land (ha)	Cultivated land (ha)	Irrigable area (ha)	N
Rain-fed dependent	2.2	1.5	1.3	98
Bucket users	2.0	1.7	1.4	270
Treadle pump users	2.4	4.0	2.1	4
Petrol pump users	3.9	2.3	1.6	157
Electricity pump users	1.6	1.2	1.4	80
Canal dependent	1.7	1.7	1.5	32
Mean	2.43	1.77	1.44	641

The size of unused potential irrigable area per household was 54.3% of the mean potential irrigable area (which is 1.44 ha). This value is 47.5% for Ashanti, 45% for Greater Accra and 42.5% for Volta region. Based on these regional values, estimates of potential area that can be developed through farmers own investments in water-lifting technologies can be made. In 2008, the official figure for farm households in Ghana was 1,849,961 (MOFA/SRID, 2010). Of the total, it is estimated that 88.1% have potential irrigable area, which is equivalent to 1,629,014 farm households, each with about 1.44 ha potential irrigable area (see Table 4). Thus, the total area that can potentially be developed by farmers through their own investments is 2,345,780 ha. Some of the factors inhibiting the realization of this potential are presented in section 3.6.

3.3 Rate of adoption and extent of use

The adoption rates of the different water lifting technologies were calculated from the census survey involving 12,620 farm households (Table 6). The bucket is the most dominant water lifting technology followed by petrol/diesel pumps. The reasons buckets are more prevalent as reported by farmers are: low acquisition, maintenance, and operation cost; fragmented land holding (buckets offer mobility over different plots); ease of use (no special training is required); and low water requirement. The prevalence of motorized pumps was higher in Ashanti and Volta regions compared to the Northern regions of Ghana (Upper East and Upper west regions).

Table 6. The adoption rates of different water lifting technologies in five regions of Ghana

Water lifting technology	Greater Accra (%)	Volta (%)	Ashanti (%)	Upper West (%)	Upper East (%)	Total (%)
Buckets	66.8	46.3	79.0	44.2	61.5	60.5
Petrol/Diesel pump	5.7	8.7	11.4	7.6	4.5	8.3
Electric pump	0.4	24.8	0.03	0.0	0.0	7.0
Treadle pumps	0.0	0.2	0.1	0.1	0.0	0.1
N	2244	3525	3536	1891	1424	12,620

Often, different water lifting technologies are used on the same farm. For example, motorized pump owners also keep buckets. They use the two technologies at different times during the crop development stage over a season. The use of buckets and motorized pumps on the same farm is common. Procurement of motorized pumps will not stop farmers from the continued use of buckets for the following reasons:

- Farmers maintain buckets as a risk minimization strategy. For instance, when the fuel costs rise or when fuel shortage occurs farmers resort to the use of bucket technology which is more cost-effective in the circumstance, to save crops and increase farm income.
- The farmers believe that buckets and motorized pumps are used for different kinds of crops.
- The farmers confirm that buckets and motorized pumps can be used at different crop growth stages. For instance, buckets are used for nursery preparation, and immediately after transplanting to minimize crop damage

As indicated in section 3.3, a significant percentage of smallholders are aware about the different water lifting technologies but only some of them managed to use the technologies (Figure 3).

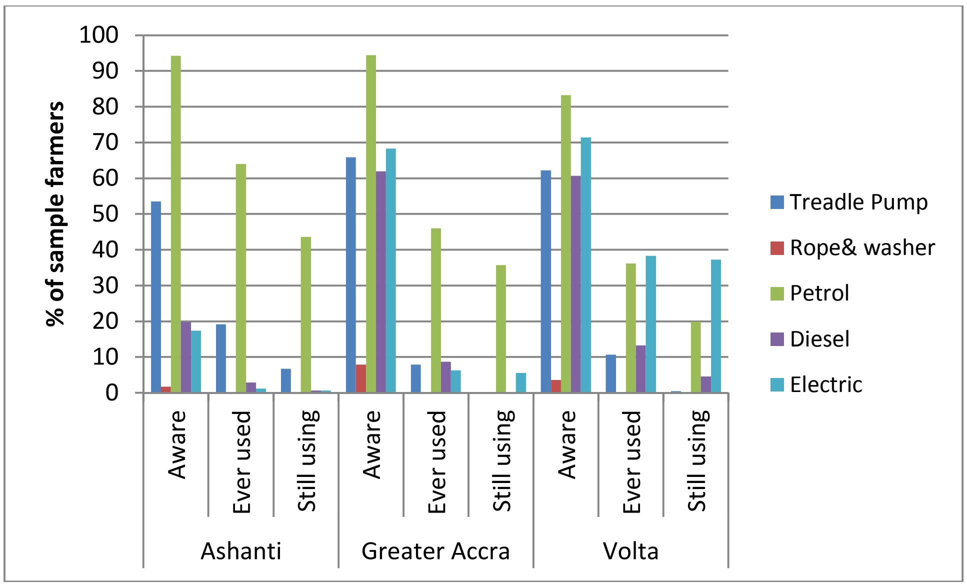


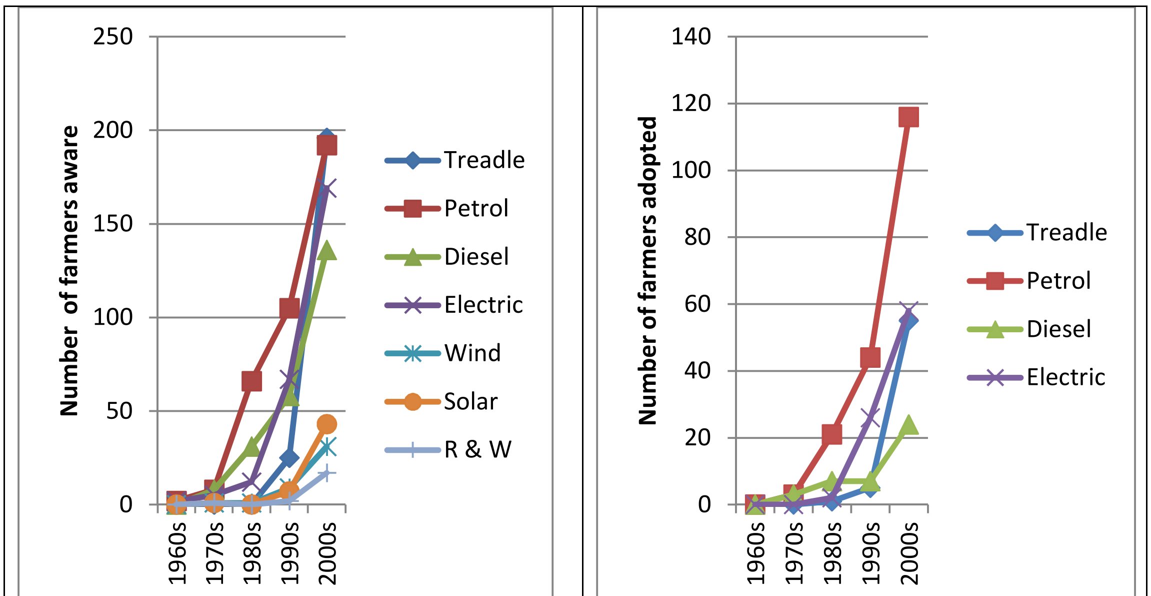
Figure 3. The adoption pattern of water lifting technologies among the sample farmers

Using the water lifting technologies adoption rates presented in Table 6 and the regional estimate of the number of farm households (MOFA, 2008); the number of small motorized pumps (excluding electric pumps) in Ghana was estimated to be about 169,624. Official import data from the Ghana Customs Excise and Preventive Service (CEPS) indicates that about 65,275 pumps and accessories worth US$8,064,760.4 were imported into Ghana between 2003 and May 2010 alone. It is estimated that there are 186,000 hectares of land irrigated by water lifting technologies. For comparison, the total area irrigated by public irrigation systems including small reservoirs and dugouts in 2009 was about 13,301 hectares (Namara et al., 2011).

3.4 Dynamics of water lifting technologies adoption

Technology adoption involves in two interrelated steps. First, the adopters have to be aware of the technology. Second, the adopters practically apply the technology if they are convinced of the benefits. Some farmers were aware of petrol and diesel pumps as far back as the late 1960s and early 1970s. However, the majority reported first becoming aware of petrol and diesel pumps in the 1980s (Figure 2). The majority reported that they first learned about electric pumps beginning in the1990s. The proportion of sample farmers who are aware of solar, wind, and rope and washer (R&W) pumps is lower. These pumps are relatively recent introductions and the majority of the sample farmers learned about them only in the early 2000s. The most important information sources for first-time learning about these water lifting technologies are: other farmers, Ministry of Food and Agriculture, the media, farmer cooperatives, and market women. Other sources include salespersons, schools, welders, road contractors, miners/engineers, well drillers, and illegal gold miners.

Awareness does not always entail practical use of the technology. Figure 4 presents the time line of actual use of the water lifting technologies. Despite awareness, no farmers are using rope and washer, wind, or solar pumps. For petrol, electric, and diesel pumps, there was a sharp increase in the rate of adoption from 1990 onwards, especially for petrol pumps.



Year of first awareness	Year of first adoption

Figure 4. The dynamics of adoption of water lifting technologies

The water lifting technology adoption pattern is found to be dynamic, meaning the technologies may be adopted and then dis-adopted due to economic and other reasons. In the assessment of the dynamics of water lifting technology adoption among 156 farmers surveyed in 2005 and again included in the 2010 survey in Ashanti and Volta regions, it was found that the use of treadle pumps has significantly diminished, while the use of motorized pumps has significantly increased (Table 7). The main reasons for the abandonment of treadle pumps as revealed by farmers are in order of significance: high labor requirement, the limitation of the area that can be irrigated, affordability, and unavailability of spare parts. The water lifting efficiency of treadle pumps promoted was found to be technically inferior to even buckets. This, coupled with the drudgery involved in their application, contributed to the decline in the number of treadle pumps in use.

Table 7. Dynamics of water lifting technologies adoption in Ashanti and Volta regions

Water lifting Technologies	Ashanti (%)		Volta (%)	
	2005	2010	2005	2010
Use of treadle pumps	52.7	12.5	30.1	1.9
Use of buckets	40.0	87.5	43.4	63.0
Use of petrol/diesel pumps	1.8	46.9	7.4	13.0
Use of electric pumps	0.0	3.1	19.1	37.0

3.5 Depth of poverty outreach of water lifting technologies

The poverty outreach of water lifting technologies was assessed by drawing bar graphs of the distributions of the water lifting technology adopters and rain-fed dependent farmer's samples by MPI quintiles and visually inspecting the distribution patterns (Figure 5). By default, the bars for rain-fed dependent farmers are expected to be equal in size across the MPI groups and, if water lifting technologies are poverty neutral or equally accessible to all categories of farmers, the distribution of adopters is expected to follow a similar pattern to that of entirely rain-fed dependent farmers. However, this was not true in the present case as can be observed from the figures. At the moment, the richest 20% of the farming population are the most prominent adopters of water lifting technologies. This is particularly true for the Ashanti region. It is noteworthy that the majority of farmers who had access to canal irrigation are among the richest 20% category.

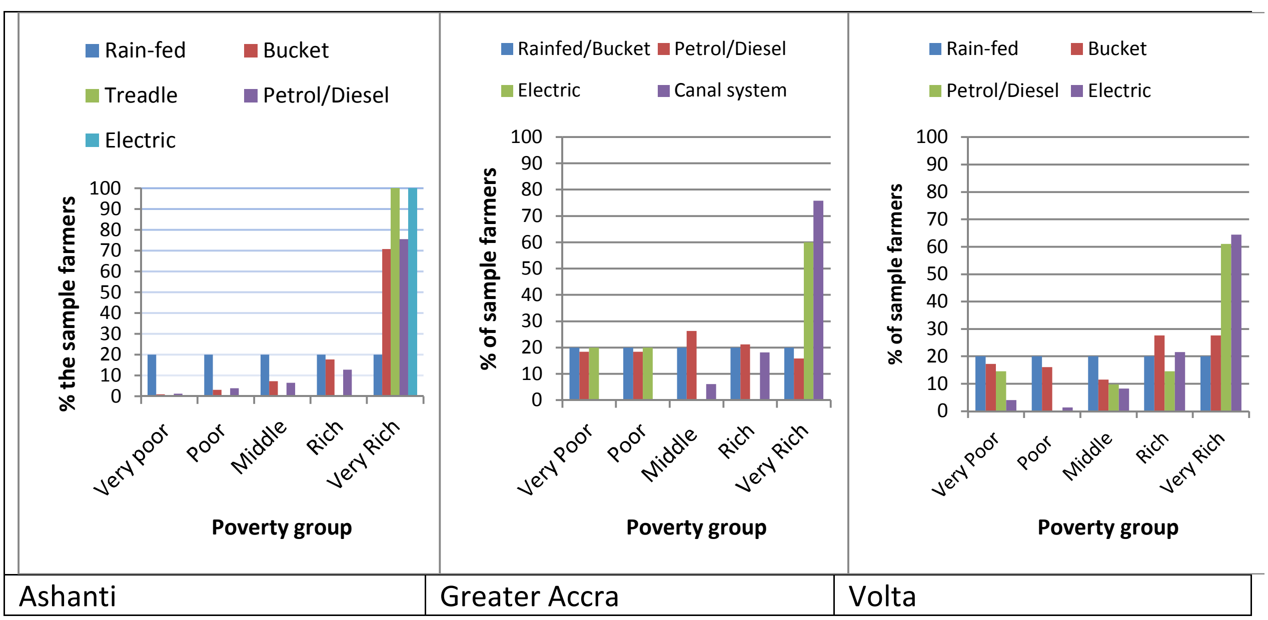


Figure 5. Poverty outreach of water lifting technologies

3.6 Comparisons of cropping pattern and yield

Vegetables dominated farmer's cropping patterns during the dry season. There is difference in cropping pattern among the different irrigation typologies. Vegetables constituted a mere 3.8% of the irrigation area of canal irrigation systems, whereas the cropped areas for rice and maize constituted about 88.7% of the total area. Farmers using buckets tended to grow diverse crops than motorized pump users. Two vegetables crops, namely pepper and okra constituted at least 53% of the area cultivated by motorized pump users. The most important crops in terms of acreage are pepper (23.0%), okra (19.3%), rice (13.9%), onion (10.6%), tomato (8.7%), maize (8.1%), and garden egg (6.9%) respectively. These crops together constituted over 90.5% of the total irrigated area during the dry season of 2008/2009 (table 8)

Table 8. Cropping areas (ha) during dry season of 2008/2009

Irrigation typology / Crops	Bucket	Petrol/ Diesel	Electric	Canal system	Bucket + Motorized Pumps	Petrol & Electricity	Total
Rice	0.0	5.67	0.0	32.8	2.2	0.0	40.67
Maize	5.22	2.43	0.41	1.0	15.0	0.2	24.26
Vegetables	72.1	37.92	25.47	1.42	73.31	10.23	220.45
Other crops*	5.06	0.0	0.0	2.84	0.45	0.0	8.35
Total	82.38	46.02	25.88	38.06	90.96	10.43	293.73

*Other crops are: Groundnut (0.5 ha), Cassava (3.24 ha), Oil palm (0.81 ha), Sugarcane (3.85ha)

For the wet season cultivation, maize, cassava, and cocoa were the major crops grown by rain-fed dependent farmers, occupying about 73.6% of their total cultivated area (table 9). Vegetables constituted 12% of the cultivated area. For farmers using buckets, maize, tomato, and onion were the major crops grown occupying 61.3% of the cultivated area. The corresponding figure for vegetables is about 55.4%.

Motorized pump owners cultivated diverse crops during wet season. The major crops grown are maize, okra, and onion (occupying 52.2% of the area). Vegetables occupy about 65.2% of the total cultivated area for this group of farmers. Farmers using a combination of bucket and motorized pumps for irrigation, grew tomato, onion, and maize occupying 53.8% of their cultivated area. Vegetables occupy 73.6% of their total cultivated area.

Table 9. Wet season cropping area (ha) during 2008/2009

Crops	Rain-fed	Bucket	Motorized pump	Canal system	Bucket+ Motorized Pumps	Total
Maize	42.06	36.77	24.91	2.84	16.3	122.88
Rice	2.75	2.03	10.51	29.59	7.09	51.97
Vegetables	12.75	72.45	76.03	3.15	110.66	275.07
Perennial/biennial*	23.78	11.34	4.26	0.0	12.86	52.24
Groundnut	1.22	0.0	0.0	0.0	0.0	1.22
Cassava	21.31	5.94	1.13	0.81	3.35	32.54
Cocoyam	0.2	1.11	0.04	0.0	0.1	1.45
Yam	1.32	1.19	0.04	0.0	0.2	2.75
Total	105.42	130.83	116.92	36.39	150.56	540.12

*The perennial and biennial crops include cocoa (31.19 ha), Plantain (10.41 ha), Oil palm (6.28 ha), sugarcane (3.95 ha), and mango (0.41 ha)

The most important crops grown by famers who depend on canal irrigation were rice, maize, and pepper. Rice occupied about 81.3% of their total cultivated area during the wet season, while vegetables constituted 8.6% of the cultivated area. Maize was the dominant crop during the wet season constituting 22.8% of the total area cultivated by all farmers during wet season. Vegetables dominated the farming systems of farmers who adopt water lifting technologies, whereas rice dominated the farming systems of farmers who practice canal irrigation. Maize and cassava were the most important crops cultivated by rain-fed dependent farmers.

The dry season cropping pattern differs markedly from the wet season cropping patterns. Vegetables occupied 75.3% of the cultivated area during the dry season followed by cereals (mainly rice and maize), which occupied 22%. All other crops covered 2.8%. During the wet season, the share of vegetables was reduced to 51.1%, while the share of cereals increased to 32.5%. The share of all other crops increased to 16.7% during the wet season. The net cultivated area for the sample farmers was 540.1 ha, with a gross cultivated area of 833.9 ha, which amounted to an average cropping intensity of 1.54.

3.7 Comparison of crop yields

Comparisons of dry season and wet season crop yields are presented in tables and table respectively. For most of the crops for which yields were compared (i.e., for crops that are cultivated under all irrigation typologies), motorized pump irrigators registered better crop yield. But yields observed for canal irrigators are generally lower. No clear yield difference could be observed between the crops grown during the 2008/2009 wet season (table 10 and 11).

Table 10. Comparison of dry season crop yields (t/ha)

Crop	Bucket	Motorized Pumps	Gravity	Bucket + Motorized Pumps
Bean (cowpea)	0.6	-	-	2.9
Groundnut	-	-	11.2	6.7
Cassava	2.7	-	-	-
Maize	1.7	1.7	0.7	1.4
Rice	-	2.5	2.7	5.7
Carrot	-	4.2	-	-
Cabbage	-	38.0	-	15.9
Garden egg	-	11.1	-	6.9
Cucumber	2.7	19.6	-	2.6
Okra	2.8	9.6	0.3	3.8
Onion	5.0	5.3	-	5.9
Pepper	5.7	7.3	0.5	3.9
Tomato	4.1	6.0	-	4.7
Watermelon	3.1		-	3.0

Table 11. Comparison of wet season crop yields (t/ha)

Crop	Rain-fed	Bucket	Motorized pumps	Bucket + Motorized pumps	Canal System
Rice	4.0	4.1	3.0	4.0	4.2
Maize	1.1	1.1	2.9	2.1	2.4
Pepper	2.4	3.1	2.5	3.3	20.7
Okra	4.6	2.6	9.3	5.0	2.0
Onion	-	7.2	8.1	6.5	-
Tomato	21.2	9.5	14.3	8.9	-
Garden egg	10.8		13.4	7.1	-
Bean (cowpea)	0.3	0.7	1.0	1.9	-
Carrot	-	-	5.2	-	-
Cabbage	-	3.5	26.8	39.0	-
Cucumber	-	-	-	5.4	-
Watermelon	-	-	-	1.2	-
Cauliflower		7.7			
Groundnut	0.4	-	-	-	-
Cassava	12.5	4.6	10.7	15.9	-
Cocoyam	15.3	3.1	-	22.5	-
Plantain	4.7	3.8	-	5.4	-

3.8 *Gross margin analysis*

Out of the 694 fields cultivated by farmers during the 2008/2009 dry season, 17.8% registered negative gross margins. The corresponding values for petrol/diesel pump, electric pump, canal and bucket irrigators was 16.5% (N=84), 28.6% (N=70), 6.5 %(N=31), and 15.6 %(N=229), respectively. The major reasons for the negative gross margins were crop damages due to pest infestation, lack of water, excessive water due to unexpected rain, and application of wrong herbicide rates which damaged the crop. For most crops, except maize and lettuce, for which yield comparisons were made, motorized pump owners obtained higher gross margins during the dry season (table 12).

Table 12. Mean gross margins per ha in for different crops by irrigation typology during the dry season

Crops	Bucket	Motorized Pumps	Bucket+ Motorized Pumps	Canal system
Cereals				
Maize	211.2	-1442.5	329.1	256.3
Rice	-	625.1	1401.5	985.9
Vegetables				
Cabbage	1899.1	1549.7	2898.2	-
Carrot	54.7	2212.6	-	-
Cucumber	721.3	12457.0	772.9	-
Garden egg	809.6	3738.8	1590.1	-
ILV	248.9	1980.0	-	-
Lettuce	6146.1	278.2	-	-
Okra	1275.1	2796.7	-282.2	2563.9
Onion	2830.1	4032.0	5533.2	-
Pepper	2640.8	3975.3	3534.4	2136.0
Spinach	297.3	788.1	3120.5	-
Tomato	2006.8	2343.6	3108.9	-
Cauliflower	-879.0	-	1756.2	-
Tinda		3012.0		
Watermelon	766.8	-	541.3	-
Beans (cowpea)	106.7	-	368.2	-
Groundnut	-	-	764.8	-
Cassava	140.3	-	-	2425.7
Oil palm	-70.4			
Sugarcane	-253.1			-146.9
Cocoa seedling			36607.0	

Comparison of mean gross margins by irrigation typologies (table 13) indicated that motorized pump owners obtained significantly higher returns compared to bucket and canal irrigators. The least gross margin was obtained from canal irrigators.

Table 13. Mean gross margins for different irrigation typologies during the dry season

Irrigation typology	Gross margin(US$/ha)	N
Buckets	1970.8	238
Petrol-Diesel	2667.3	85
Electric	1534.5	70
Petrol-Electric	4187.7	23
Buckets-Motorized Pumps	2436.3	232
Gravity	1219.5	33

Table 14 presents data on gross margins obtained from different wet season crops grown under different irrigation typologies. Comparison of these gross margins, did not show any clear patterns (table 14).

Table 14. Mean gross margins per ha in for different crops by irrigation typology during the wet season

Crops	Rain-fed	Bucket	Motorized Pumps	Bucket+Motorized pumps	Canal system
Cereals					
Maize	268.3	206.3	823.6	548.1	728.0
Rice	1006.1	2520.7	1532.4	1827.0	2450.4
Vegetables					
Cabbage	-	5694.4	3228.2	3785.3	-
Carrot	-	4702.9	433.7		
Cucumber	-	-	-	1182.1	-
Garden egg	7236.2	2559.7	3738.8	1894.5	-
ILV	1756.2	128.5	7276.1	5144.0	-
Lettuce		2551.9	-	-	927.2
Okra	2451.4	760.0	4018.5	1667.3	312.5
Onion	1417.3	5902.6	5076.7	3814.1	-
Pepper	5157.3	2480.9	1599.2	3891.9	2309.9
Tomato	12150.4	6764.9	6349.9	6762.6	-
Cauliflower	-	6435.8	-	600.0	-
Watermelon	-	-	-	168.7	-
Beans (cowpea)	-228.1	-175.3	223.5	1769.1	-313.6
Groundnut	-232.2				
Cassava	1203.0	1123.4	1608.2	1472.4	698.8
Cocoyam	891.4	2238.5	-1219.8	21175.3	-
Oil palm	646.1	-56.2	651.0	-	-
Sugarcane	-	1612.6	2971.2	-	-
Plantain	1450.5	892.5	-	3714.2	-
Cocoa	541.7	1150.6	244.9	160.3	-
Mango	-	30168.9	-	-	-
Yam	6085.2	3225.0	1866.7	2805.9	-

However, comparisons of overall mean gross margins for different farm typologies (table 15) indicated that farmers with access to water-lifting technologies obtained higher mean gross margins followed by canal irrigation.

Table 15. Gross margin by farmer category: wet season

Category	Gross margin (Ghana Cedi = US$/ha)	N
Rain-fed	1702.1	177
Buckets	3559.3	294
Petrol-Diesel	2820.1	110
Electric	4601.0	60
Petrol-Electric	3747.3	16
Buckets+ MP	3701.1	244
Gravity	1914.9	42 ????

3.9 Constraints to adoption of water lifting technologies and expansion of private smallholder irrigation systems

As indicated in section 3.2, most farmers have potential irrigable area that can be developed using water lifting technologies. However, this potential is yet to be realized. The major reasons for underuse are:

- limited access to equipment and accessories
- lack of access to finances
- high operational costs, specifically energy and labor
- output market risk, and
- inadequate institutional and policy support (e.g., research and extension)

Some location specific constraints were also mentioned. These are: water quality (saline water problem); flooding; high initial land development costs; and occupation of the land with tree crops (e.g., oil palm).

3.9.1 Access to equipment and accessories

For those who had access, a wide range of pump brands and sizes were available. The most common brand of petrol and diesel pumps was Honda (77.2%), while Sear was the most frequently encountered brand for electric pumps (58.5%). These pumps are available in different sizes. The size of most petrol pumps ranged between 2.5 to 5.5 HP (79.1%), while electric pumps ranged between 1 to 2 HP (94.8%). The size of diesel pumps tended to be higher, ranging widely between 5-25 HP (83.3%). All in all, about 30 brands of small motorized pumps were reported to be in use by farmers. However, 76% of the farmers reported that they had problems in finding the type of pumps they needed. Most farmers buy motorized pumps from agro-retail shops. Manual pumps are usually obtained from NGOs such as Enterprise Works or IDE. Petrol pumps are purchased from the nearest big towns, whereas diesel and electric pumps are obtained from distant towns. Some farmers reported purchasing petrol and electric pumps from outside Ghana (4.6% for petrol and 8.8% for electric pumps). The pumps on sale are sub-standard quality. Often farmers scrap pumps because of minor defects and buy new ones.

There are estimated 1500 agro dealers with 3505 agro-input sales points in Ghana (IFDC et al., 2010). An SMS was sent to a total of 3400 agro-input sales points asking whether they sell pumps for agricultural use. Only 102 responses where obtained, of which 36 responded that they do sell pumps (Figure 6). Thus, the water lifting technology supply chain is not well developed in Ghana relative to other agricultural inputs (e.g., seed and fertilizer) that often have accorded the highest government and donor priorities. These findings are similar to the study conducted in Zambia.

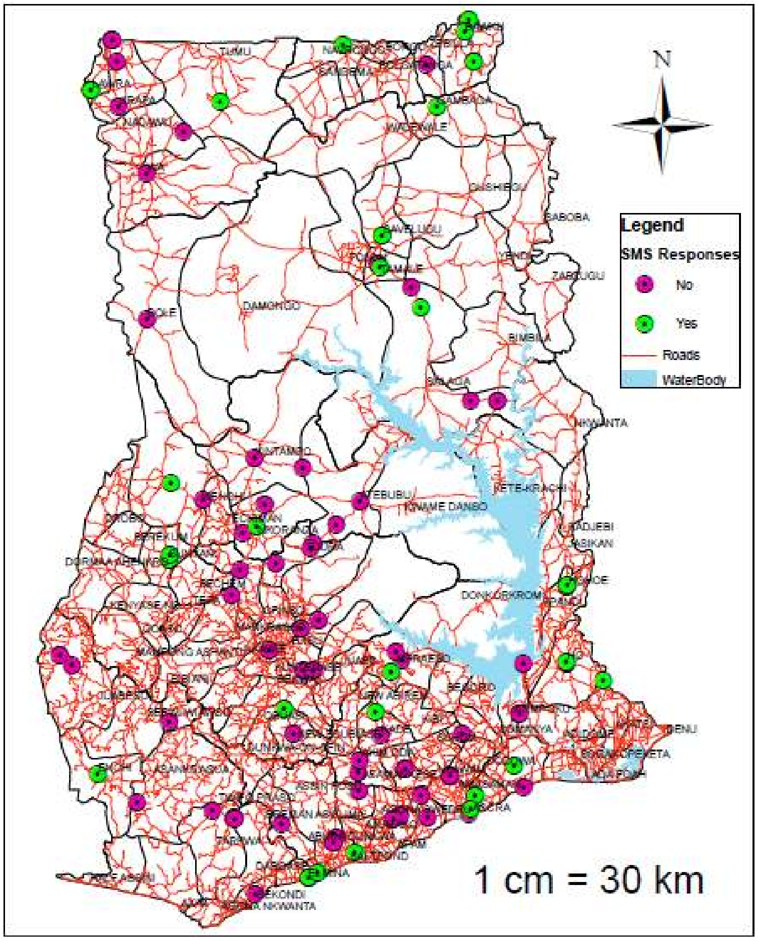


Figure 6. Network of agro-input and small motorized sales points in Ghana

The majority of the farmers own one or two pumps, few farmers own three or more. Buckets, treadle pumps and electric pumps are mainly privately owned. A considerable number of farmers access petrol and diesel pumps through rental arrangements (Table 16). Pump rental arrangements are particularly prevalent in Greater Accra and Volta regions.

Table 16. Pump ownership patterns

Ownership	Petrol (%)	Diesel (%)	Electric (%)
Private	50.4	67.6	95.2
Communal	8.6	5.5	1.2
Rental	38.5	18.9	3.6
Friends or Relatives	2.6	8.1	0.0
N	234	37	83

Pumps can be rented for a day, for a season, for a year or even on an hourly basis. Rentals on a daily basis were the most common. The rental rate varied in different locations and was influenced by the source. The mean rental rate charged for a petrol pump was about US$9 per day. The per season rate is about US$18.4. The rental cost for a diesel pump is not that different from that of petrol pump, about US$8.5 per day or US$21.1 per season. The seasonal rental rate ranges from US$28.2 to US$107. On average, the sample households rented motorized pumps for 22.2 days. Length of rental depends on the circumstances of the farmers and ranges from 2 to 120 days in a season.

The price of pumps paid by farmers is highly variable for similar pump models and sizes because of an inefficient pump marketing system. The Government of Ghana has established a policy to exempt pumps from certain taxes as part of the general import provisions for agricultural machinery and implements. However, the tax exemption policies do not seem to have an effect on the prices paid by farmers. Furthermore, there are serious weaknesses in the supply chain of motorized pumps due to a lack of transparency in the procurement process.

All goods imported into Ghana are subject to import duties, import VAT, import NHIS levy, processing fee, ECOWAS levy, export development and investment (EDIF) levy and IRS tax deposit. These taxes are calculated on the CIF value of the imported products. As per the tax regulations of Ghana under the Custom Excise and Preventive Service (CEPS) Harmonized Commodity Codes and Tariffs Schedules, agricultural products are exempted from import duty (0.5%), import VAT (12.5%), and import NHIL (2.5%). For motor pumps used in agriculture, the taxes paid are: processing fee (1%), ECOWAS levy (0.5%), EDIF levy (0.5%), and IRS tax deposit (1%). In addition to these taxes, port charges paid on imports include handling charges, rent, un-stuffing and re-stuffing, where applicable.

The process of obtaining tax exemption is cumbersome and lengthy. The process involves an application for a tax exemption waiver on the pumps through the Ministry of Food and Agriculture. According to the authorities at the Ministries and CEPS, this exemption process should take between 2-3 days. However, according to the importers, it takes between three weeks and a month to get it sorted. At the port, clearing normally takes one day. However, because of the delays at the ministries and the other agencies, the port clearing process also becomes lengthy. The cumbersome clearing processes results in an estimated additional cost of 5-8%.

3.9.2 Finances

163 of the total 494 sample farmers borrowed US$96,658.5 during the 2008/2009 season. These loans were obtained, in order of significance, to procure fertilizer, herbicides, insecticides, seed, fuel, and equipment. The main sources of finance for the procurement of inputs and agricultural equipment are banks, individuals such as market women, friends or family, and NGOs. The role of market women in agricultural input finance is quite substantial in Ghana. Investment in pumps is mainly from farmers' own capital.

There are three modalities of loan repayment: in cash, in kind and both in cash and in kind. The majority of the farmers repay loans in cash (78.2%). Some farmers pay in kind (19.8%). Others farmers pay both in cash and in kind (2.0%). The acquisition of loans may involve obligations such as selling outputs to the creditor. Some 53.1% of the 96 farm households who obtained loans from un-official sources reported that they had an obligation to sell part or all of their crop outputs to their creditors.

Some farmers complain that banks often reject their loan requests due to lack of collateral or the general lack of interest by banks in servicing smallholder farming. Farmers also claim that the interest rates levied are unacceptably high (Figure 7). The mean interest rate reported for borrowing money to acquire inputs was 26.9% (N=80), ranging from as low as 5% to as high as 60%. For this reason, farmers resort to sources such as market women or individuals. Accessing loans from such sources is prompt and is not constrained by excessive procedural glitches and delays (Figure 8). The majority the farmers obtain loans within 30 days of application for the loans.

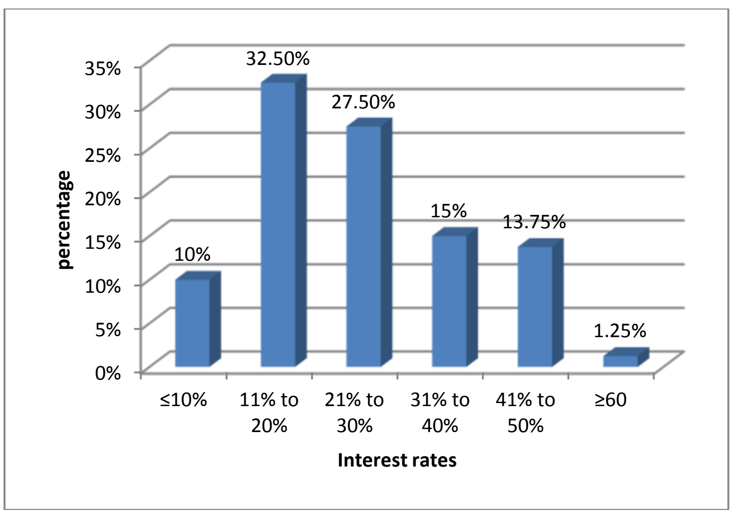


Figure 7. Interest rates for input procurement loans

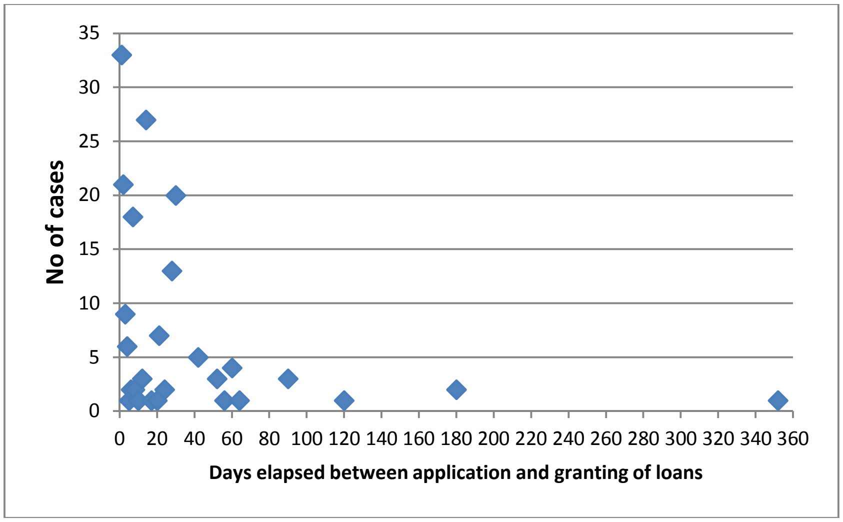


Figure 8. Ease of accessing loans

3.9.3 Operation and maintenance costs

Lift irrigation systems, particularly those based on small motorized pumps, use petrol or diesel as fuel or electricity to operate pumps. The fuel cost is about US$300 per hectare. This is in addition to the often high cost of investment. For instance, a hectare of shallow groundwater based sprinkler irrigation in Keta district of Ghana costs US$63 for tube well development; US$328.7 for electric pump; US$ 1565.3 for pipe network and sprinklers; and US$259.3 for electricity installation.

There is no special provision for agriculture in Ghana's energy policy as observed for instance in many Asian countries such as India (Shah et al. 2008; Mukherji, et al. 2009). Farmers access fuel at the going market rate. Similarly, there is no special consideration in the electric tariff system. The Electricity Company of Ghana (ECG) has three tariff systems: residential, non-residential, and special load tariff (Table 17).

Table 17. Electricity tariffs in Ghana as in March 2011 Gazette, effective March 1, 2011

Customer Group	Energy Charge (GHc/kWh)	Capacity Charge (GHc/KVA/Month)	Service Charge GHc/Month)
Residential			
0-50	0.0950	-	1.00
51-300	0.1595	-	1.5
301-600	0.2070	-	1.5
>600	0.2300	-	1.5
Non-Residential			
0-300	0.2293	-	2.5
301-600	0.2440	-	2.5
>600	0.3850	-	2.5
Special Load Tariff			
Low Voltage	0.2390	14.0	10.0
Medium Voltage	0.1850	12.0	14.0
High Voltage	0.1700	12	14
High Voltage-Mines	0.2700	14.0	14.0

Small pump electricity consumption falls under the non-residential tariff system. The energy charge under the non-residential system is high, but the service charge is lower as compared to the Special Load Tariffs, except for mines. On a per hectare basis, the fuel cost of operating pumps is higher than electricity. Moreover, the operation and maintenance cost of a diesel pump is higher than petrol pump (Table 18). Consequently, there are more petrol pumps in use in Ghana.

Table 18 Maintenance and repair costs

Pump	Maintenance Frequency/annum	Mean maintenance cost/annum (US$)	Repair frequency/life span	Mean repair cost (US$)
Treadle	3-4	5.1		
Petrol	3	32.3	1.58	35.7
Diesel	5	167.6		55.6
Electric	2.2	71.6	2.5	97.8

3.9.4 Marketing risk

Vegetables dominate the cropping patterns during the dry season. The most important crops in terms of acreage are pepper (23.0%), okra (19.3%), rice (13.9%), onion (10.6%), tomato (8.7%), maize (8.1%), and garden egg (6.9%). These crops together constituted over 90.5% of the total crops on irrigated area during the dry season of 2008/2009 (Table 19). Farmers face a significant marketing risk due to the perishable nature of these crops.

Table 19. Cropping areas (ha) during dry season of 2008/2009

Crops	Bucket	Petrol/ Diesel	Electric	Canal system	Bucket + Motorized Pumps	Total
Rice	0.0	5.67	0.0	32.8	2.2	40.67
Maize	5.22	2.43	0.41	1.0	15.2	24.26
Vegetables	72.1	37.92	25.47	1.42	83.54	220.45
Other crops*	5.06	0.0	0.0	2.84	0.45	8.35
Total	82.38	46.02	25.88	38.06	101.39	293.73

*Other crops are: Groundnut (0.5 ha), Cassava (3.24 ha), Oil palm (0.81 ha), Sugarcane (3.85ha)

The major output market outlets include wholesalers, traders, poultry farmers, export agents, cooperatives, consumers, food sellers or retailers, processors, NGOs, and banks. The major market outlets for the sample farmers were wholesalers and traders. Direct sales to consumers and processors were limited, especially for vegetables. Export agents are mainly engaged in purchasing irrigated vegetables and fruits. About 78.4% of the vegetable farmers responded that the place of sale of their outputs were at the farm gate or in the nearest big town. The mean distance of markets from farms was different for the different regions. These values are 26.1 km, 10.3 km, and 9 km for Ashanti, Volta, and Greater Accra regions, respectively.

During the wet season, the mean ratio between expected high and low prices for vegetables was about 3.3. The price variability was greatest for cabbage, pepper, tomato, lettuce, and garden egg (Figure 9). The mean ratio between expected high and low prices for staple crops during the wet season was 1.6, which is very low compared to the ratio for vegetables. Farmers seem to have guaranteed prices for cocoa, since no difference in the expected low and high price was indicated by respondents. During the dry season, the mean ratio between high and low prices for vegetables was 2.4. The mean ratio between the expected low price during dry season and the expected low price during wet season for vegetables was 2.3. The corresponding values for the ratio between dry season high and wet season high is 1.7. Vegetable prices were generally higher during dry season, and crop prices were generally less variable during the dry season compared to the wet season.

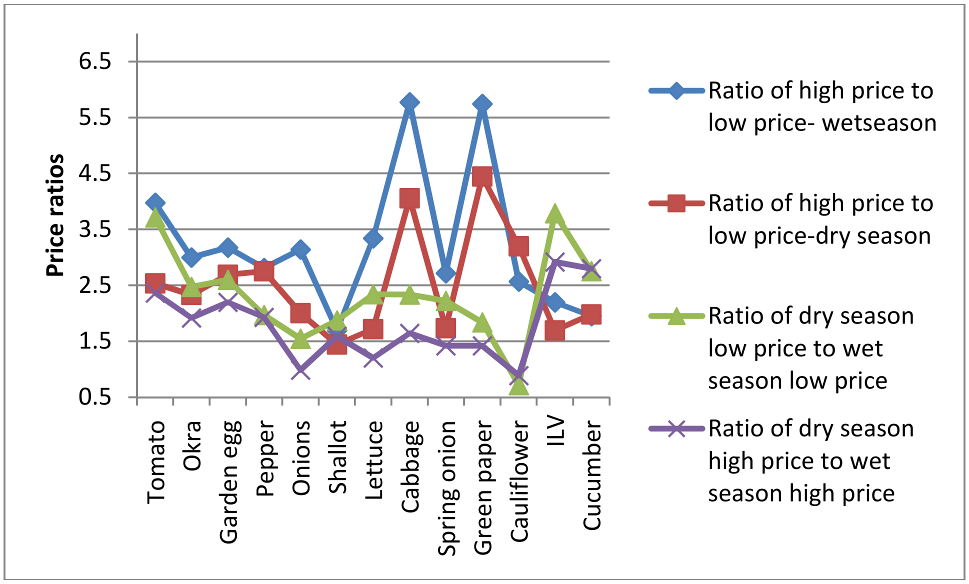


Figure 9. Price variability for vegetable crops

The availability of processing facilities to add value to agricultural outputs influences the profitability of crops and indirectly the adoption of water lifting technologies. The agricultural processing facilities most available to farmers are maize and rice millers, tomato and pepper paste makers and oil palm processor.

3.9.5 Inadequate research and extension support

Generally, irrigation extension is poorly developed in Ghana and SSA (Namara et al. 2011). Farmers had more access to public agricultural extension services during wet season and public irrigation systems are better serviced as compared to smallholder lift based irrigation systems. On the other hand, farmers engaged in lift irrigation had more access to un-official extension services as compared to rain-fed farmers. The inadequacy of extension service is partly a reflection of the country's extension policy, which gives priority to staple food and tree crops such as cocoa.

Similar to the case for the extension system, the research needs of crops grown using water lifting technologies is not adequately addressed as these crops do not fall within the priority research areas of Ghanaian agricultural research institutes. Thus, farmers lack professional advice on agronomic and crop protection aspects of vegetable and fruit crop production. Moreover, at present no advice is available to farmers on the amount of water or irrigation schedule they should use for most vegetable and fruit crops. Production of irrigated vegetables is an intensive enterprise in which farmers' crop up to four times a year. Their knowledge of cultivation techniques and use of inputs is poor.

4. Conclusions and Recommendations

4.1 Conclusions

Ghana and other SSA countries are planning to expand cultivated area under irrigation to cushion the agricultural sector from the vagaries of weather and to modernize the sector. This can be attained through public and private investment initiatives. The performance of past public investments has been dismal. Despite a concerted government engagement in the sector since 1960s, the total irrigated area through publicly funded projects, including that of NGOs, is 13,301ha (Namara et al., 2011). On the other hand, smallholder driven private irrigated area is estimated to be 186,000 ha. This scenario is a rule rather than the exception in most Sub-Saharan African countries. The smallholder driven private irrigation sector is largely a lift irrigation system based on a variety of water lifting technologies such as rope-and-bucket system, rope and washer pump, diaphragm pump, treadle pump, animal traction devices (e.g. *delou* in Niger), and small engine pumps (Pukey and Vermillion, 1995).

On average, the sample farmers had 1.44 ha land that can be potentially developed for irrigation using water lifting technologies. Extrapolation of the sample values indicates that there is about 2,345, 780 ha land that can be developed for irrigation using water lifting technologies in Ghana. The realization of this potential depends on the pattern and rate of adoption of water lifting technologies. The major constraints to the realization of the irrigation potential (implicitly the dissemination of water lifting technologies) are:

- limited access to equipment and accessories
- lack of access to finances
- high operational and maintenance costs
- output market risk, and
- inadequate research and extension support.

4.2 Recommendations

Private smallholder lift irrigation is increasing but not at the desired pace. This development is often not well noticed. Investment in smallholder lift irrigation systems should be a major sector initiative as it would have a significant impact on poverty and food security. To realize this potential, improvements are required in the entire value chain of lift irrigation systems. The priority intervention areas for improving the rate of adoption of water lifting technologies, especially small motorized pumps, include:

- Widen access to equipment and accessories through improving the supply chain of water lifting technologies.
- Institute innovative financial products..
- Give special consideration to smallholder irrigated farming in the energy tariff setting (e.g., fuel and electricity rates).

- Improve the capacity of farmers to optimally use the pumps once acquired by:
    - providing training to farmers on pump selection and basic maintenance routines;
    - preparing simple manuals or leaflets in local languages containing basic information on pump selection, installation, and maintenance;
    - providing training for potential maintenance service providers such as unemployed youth in the communities and pump distributors; and
    - establishing pump quality standards.
- Develop an information management system to monitor, evaluate, and support the pump supply chain and gauge the development of smallholder lift irrigation systems.
- Improve output price information dissemination and encourage crop or enterprise diversification to offset the debilitating effects of marketing risk.
- Prioritize agronomic and water management research on crops of prime significance to lift irrigation systems.
- Consider the special extension service needs of lift irrigation systems

However, a word of caution is required here for the injudicious expansion of pump based irrigation can have serious negative environmental and water resources implications. Thus, improving the environmental performance of pump based irrigated agriculture is important for its long-term sustainability.

5. References

Abric, S., Sonou, M., Augeard, B., Onimus, F. Durlin, D., Soumaila, A., and Ga dElle, F., 2011.Lessons Learned in the Development of Smallholder Private Irrigation for High-Value Crops in West Africa. Joint Organizational Discussion Paper, Issue 4, The World Bank, 1818 H Street, NW, Washington, D.C.

Cochran, W.G., 1977. Sampling Techniques (3rd ed.). New York: John Wiley & Sons.

International Center for Soil Fertility and Agricultural Development (IFDC), Ghana Agri-Input Dealers Association (GAIDA), and Ghana Agricultural Association Business and Information Center (GAABIC), 2010. Directory of Ghana Agri-Input Dealers. Ghana Agricultural Associations Business and Information Center.

MOFA/SRID.2010. Agriculture in Ghana. Facts and Figures (2009). Ministry of Food and Agriculture

Mukherji, A., T. Shah and Verma, S., 2010. Electricity reforms and their impact on groundwater use in States of Gujarat, West Bengal and Uttarakhand, India. *On the Water Front: Selections from the 2009 World Water Week in Stockholm*. Stockholm, Stockholm International Water Institute (SIWI): 100-107.

Namara, R.E., Horowitz, L., Nyamadi, B., and Barry, B., 2011. Irrigation development in Ghana: past experiences, emerging opportunities, and future directions. Ghana Strategy Support Program (GSSP). GSSP Working Paper No.0027, International Food Policy Research Institute.

Pukey, D.R., Vermillion, D., 1995. Lift Irrigation in West Africa: Challenges for Sustainable Local Management. International Water Management Institute. IWMI Working Paper No. 33.

Shah, T.; Verma, S., 2008. Co-management of electricity and groundwater: An assessment of Gujarat´s Jyotirgram Scheme, Economic and Political Weekly, 43(7):59-66