AgWater Solutions Project
Case Study

Agricultural Use of Shallow Groundwater in Ghana: A Promising Smallholder Livelihood Strategy

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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.

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Summary

Groundwater is a critical resource for human survival and economic development through mitigating the effects of drought and uncertain rainfall on agricultural production. In Ghana and in Sub-Saharan Africa, groundwater-based irrigation gets little public policy attention. The results of the limited hydrogeological studies in Ghana send mixed signals or pessimistic views about the groundwater resource potential. Consequently, groundwater resource use is centred on potable water supply for domestic use. Agricultural use accounts for less than 5% of all groundwater uses.

Despite the official pessimism, smallholders have taken the lead in using groundwater resources. A considerable proportion of the sample farmers in this study (30.9%) reported having access to groundwater that can potentially be developed. Most farmers rate groundwater as the most reliable source compared to other water sources such as rivers and streams. A significant percentage of sample farmers reported they would use potentially irrigable land provided they had access to finances and affordable energy to use groundwater and other sources.

There are four types of groundwater irrigation systems in Ghana: 1) seasonal shallow well irrigation, which is further differentiated into in-field and riverine shallow well systems; 2) permanent shallow well irrigation systems; 3) shallow tube well irrigation systems: and 4) borehole irrigation systems. Shallow wells are commonly dug near small reservoirs and dugouts that are not functioning well due to maintenance and operation related problems. The practice of using water from shallow wells dug in command areas and near reservoirs and dugouts is redefining the role of reservoirs and dugouts as a recharging mechanism. This is an area that needs consolidating to salvage the poorly functioning capital intensive reservoirs commonly found in Ghana and elsewhere in Sub- Saharan Africa.

In UER, farming is the dominant livelihood strategy for all shallow groundwater irrigation practitioners. Non-farm and off-farm activities are equally important in the livelihoods of shallow groundwater farmers from Greater Accra and Volta regions, implying the relative abundance of employment opportunities in these areas. In UER, the proportion of female headed households in the shallow groundwater irrigation practitioners group is less than their proportionate representation in the non-practicing sample. The illiteracy rate among shallow groundwater irrigators from Greater Accra and Volta region is low.

In UER, the total investment costs of riverine, in-field, permanent lined, permanent unlined shallow wells are GHC 160.80, GHC 26.00, GHC 150.00, and GHC 120.00 per constructed well, respectively. Shallow well development costs are higher in Volta and Greater Accra regions. The investment cost of a permanent shallow well is GHC 80.00 and GHC 1 54.00 in Volta and Greater Accra respectively. The investment cost for tube well irrigation is significantly higher. The major cost components for a typical tube well in Volta are tube well development, pump installation, laying out a pipe network, and electrical installation.

Vegetables are the most important crops grown under shallow groundwater irrigation constituting over 95% of the total irrigated area. UER farmers have innovatively developed on-farm water management systems that improve the efficiency of water and nutrient use. In the Volta region, farmers use sprinklers to economize on water abstracted from tube

wells. Overall, shallow groundwater-based irrigation is profitable in UER, particularly when the opportunity cost of family labor is not considered in profitability calculations. Tube well irrigation practice is also profitable in Greater Accra and Volta regions, even when the opportunity cost of family labor is considered.

In UER, labor constitutes a significant proportion of both shallow well development and the associated crop production costs. Fixed costs constitute a small portion of the total cost of production. Thus, shallow groundwater irrigation systems are suitable for a capital constrained and labor abundant area like the UER, particularly during the dry season.

In conclusion, shallow groundwater irrigation has contributed significantly to employment generation during the long dry period in the UER and during the unreliable second season in Greater Accra and Volta, particularly for youth. It has contributed to reduced mitigation and poverty reduction. It has strengthened food and nutritional security by providing macro and micro nutrients to children and mothers.

The full realization of these opportunities is hindered by the following constraints:

- lack of explicit policy and policy support;
- lack of authoritative knowledge of the resource potential and distribution;
- land tenure insecurity;
- inefficiencies in output and input marketing, including equipment supply;
- lack of efficient financing services;
- high cost of energy, particularly for those using petrol and diesel pumps;
- lack of access to electricity;
- pest and diseases attack including livestock and wildlife attack on crops;
- drudgery due to use of rudimentary tools for well drilling and water lifting; and
- the general paucity of irrigation extension services.

1. INTRODUCTION

The critical role of groundwater resources for poverty alleviation has long been emphasized. Groundwater is a critical resource for human survival and economic development in extensive drought-prone areas of south-eastern, eastern and western Africa. It offers potential to mitigate the effects of drought and erratic rainfall on agricultural production because groundwater levels are less correlated with rainfall (Foster et al., 2006; Allaire, 2009).

Ghana's agriculture is predominantly rainfed. However, irrigation is increasingly being recognised as a major intervention to address food and nutrition security as well as poverty problems in many regions of the country. Ghana's groundwater is estimated to be 26.3 km^3 per year (FAO, 2008). However, groundwater-based irrigation gets little public policy attention in either water or irrigation policies. There is no specific policy on the use of groundwater for agriculture.

The National Water Policy identifies three main geological formations: 1) the basement complex, comprising crystalline igneous and metamorphic rocks; 2) the consolidated sedimentary formations underlying the Volta basin (including the limestone horizon); and 3) the Mesozoic and Cenozoic sedimentary rocks. These formations represent 54%, 45% and 1% of the country respectively. The National Water Policy states that the potential for increasing groundwater uses faces challenges. There are saline intrusions in shallow aquifers along the coastal zone, while borehole yields in the Northern, Upper East, Upper West and parts of Brong-Ahafo regions are often insufficient with some occurrence of "dry boreholes".

Gyau-Boakye and Tumbulto (2000) have noted that increasing abstraction of groundwater has led to depletion in some areas. Recently, a hydrogeological study was conducted in the Northern, Upper East, and Upper West region to build up a scientific information database in groundwater potential under the Hydrogeological Assessment Project. Fifteen monitoring wells were successfully drilled. Initial yields from the wells indicated substantial groundwater potential in the Northern region.

The available literature on groundwater resources potential for agriculture use is mixed. Most experts suggest the allocation of limited groundwater to domestic uses. Consequently, potable water supply for domestic uses in many rural areas, particularly Northern Ghana, has been from groundwater. According to Kortatsi (1994), 84% of groundwater extracted in Ghana is used for domestic purposes. It is also used for livestock watering and for agricultural produce processing. Agricultural use is said to account for less than 5% of all groundwater use and the farmers involved are mostly small-scale operators. The use of groundwater for irrigation is mainly via shallow well, which are dug along river banks and in low-lying areas mainly in Volta, Upper East, Upper West, and the Greater Accra regions. The use of boreholes and deep wells for irrigation is beginning to gain importance.

Many borehole sites, particularly those underlain by crystalline basement rock with fractures and fissures, while suitable for boreholes are also channels for rapid transfer of pollutants. There is therefore potential for contamination from point sources including refuse dumps, latrines and unprotected water points including abandoned hand-dug wells. There are also problems with high iron and fluoride content in parts of the country including the Western, Northern and Upper East Regions. Concerns have been raised with regard to falling groundwater levels in areas where many boreholes have been drilled such as the Upper East Region of Ghana.

Study objectives

Sub-Saharan Africa is seeing growing interest on the part of governments, private foundations and multi-lateral donors in stepping up irrigation investments as a means to improve livelihoods and food security among smallholder farmers. Public irrigation development initiatives often give exclusive emphasis to developing surface water resources with little or no consideration for developing groundwater for irrigated agriculture. On the other hand, smallholders have attempted to develop groundwater-based irrigation systems autonomously or with some help form governments, NGOs, and donors. So far, little systematic socioeconomic study has been done to understand the development dynamics, economics, and impacts of these initiatives. This report endeavours to fill this knowledge gap. The specific objectives are:

- To describe the types of shallow well irrigation system in Ghana;
- To analyze the economics of smallholder groundwater irrigation;
- To assess the socioeconomic impacts of shallow groundwater irrigation;
- To assess the constraints and opportunities of smallholder groundwater irrigation systems; and
- To recommend ways to improve and expand systems.

Data and methods: Sampling design and procedure

Data were collected from selected communities in Upper East, Upper West, Ashanti, Greater Accra, and Volta regions. These regions represent the southern and coastal, semi-deciduous, transitional, and savannah agro-ecological zones of Ghana. Data collection was done in two steps. First, a census survey was implemented in selected communities where shallow groundwater irrigation is believed to be practiced. Second, a sample survey was done in the subset of communities included in the census survey. The register of farming households developed in the census survey served as a sampling frame for the sample survey. The basic sampling unit for the sample survey was determined to be the household. The sampling design adopted was stratified random sampling with probability-proportional-to-size.

Upper East Region (UER)

In the UER, the study was carried out in three watersheds: 1) Atankwidi (270 km^2); 2) Anyare (200 km^2); and 3) Yariga-tanga (Fig. 1). At 8,842 km^2, the UER constitutes about 3.7% of the total land area of Ghana. The population density is 113 per km^2, making it more densely populated than all three Northern regions, including the Brong-Ahafo region.

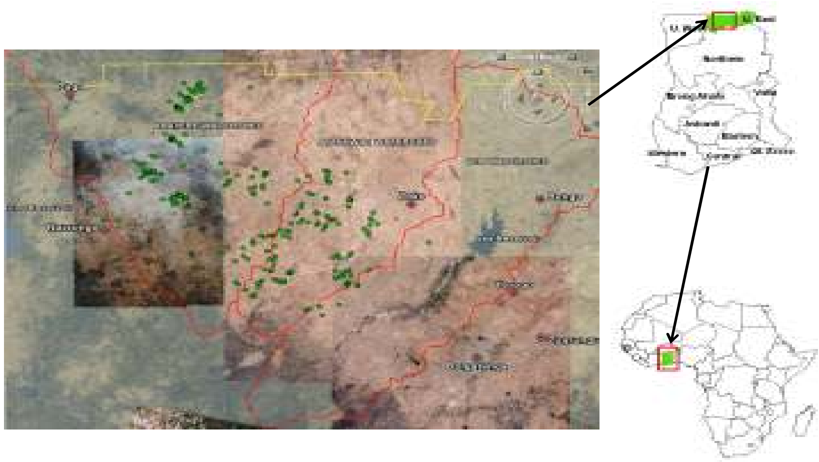

Figure 1.Map of study areas in the UER.

In UER, the procedures involved in sample selection are detailed as follows. First, 35 communities distributed in the three sub-watersheds of the White Volta Basin with potential access to shallow groundwater were identified (Fig.1). Second, a household census was conducted in each of the 35 communities to develop a sampling frame for eventual sample selection. These communities were differentiated into 2,085 compounds with 4576 farm households. A total of 20,962 people reside in these compounds. Of the total 4,576 households, 2,781 practice irrigated farming. Of the total households with access to irrigation, 1,603 households are in-field seasonal shallow well irrigators, 384 are riverine seasonal shallow well irrigators, and the remaining 512 are permanent shallow well irrigators. In total there are 5,290 in-field seasonal shallow wells irrigating 1,475.0 acres, 922 riverine seasonal shallow wells irrigating526.3 acres, and 666 permanent shallow wells irrigating261.3 acres in the entire three micro-watersheds during the 2008-2009 season. In total there are an estimated 262.6 acres of irrigated land using shallow groundwater.

Third, the identified households were stratified into purely rainfed farming households and irrigating households. The irrigating households were further stratified into seasonal shallow well irrigators, permanent shallow well irrigators, and irrigators using surface water sources (mainly small reservoirs). Finally, a total of 420 sample farmers were selected using probability-proportional-to-size sampling, in which the selection probability for each strata is set proportional to the size of the stratum measured by the total number of households in the stratum (Table 1).

Table 1. Sample size differentiated by irrigation typology.

Strata	Sample farmers
Purely rainfed farmers	141
Seasonal shallow well irrigators	212
Permanent shallow well irrigators	23
Small reservoir irrigators	40
Total	420

Ashanti, Greater Accra, Upper West, and Volta regions

Clusters of administrative regions were selected to represent the southern and coastal zones, the semi-deciduous and transition zones, and the savanna agro-ecological zones. From these regions a total 20 districts and 68 communities were selected. Then a hut-to-hut survey was conducted using a structured survey questionnaire. In total 12,620 members of farm households were interviewed (Table 2). thirty-two percent use groundwater for agriculture.

Table 2. The extent of shallow groundwater irrigation estimated from the survey.

Region	Number using groundwater	Groundwater users who use buckets as a lifting device	Groundwater users who use petrol/diesel pumps as a lifting device	Groundwater users who use an electric pump as a lifting device	Total households
Greater Accra	527	460	67	0.0	2,244
Upper East	381	NA	NA	NA	1,424
Upper West	858	NA	NA	NA	1891
Volta	2,172	1201	97	874	3,525
Ashanti	119	94	25	0	3,536
Total	4,057	1,755	189	874	12,620

NA: Data not available

Shallow wells are commonly dug near dugouts and reservoirs. Of the 381 shallow wells reported from UER, 64 were near dugouts and 128 near small reservoirs. Similarly, in UWR, 542 shallow wells were sunk near small reservoirs and 337 near dugouts. Thus, dugouts and reservoirs are being used for groundwater recharging.

The data obtained from the census survey served as a sampling frame in the subsequent in-depth sample survey. The sample survey only covered three regions, namely Ashanti, Greater Accra, and Volta (Fig. 2). Nineteen communities were selected, eight each representing rural and urban settlements, and three representing urban settlements. A total of 494 farmers were randomly selected using a multi-stage stratified sampling design.

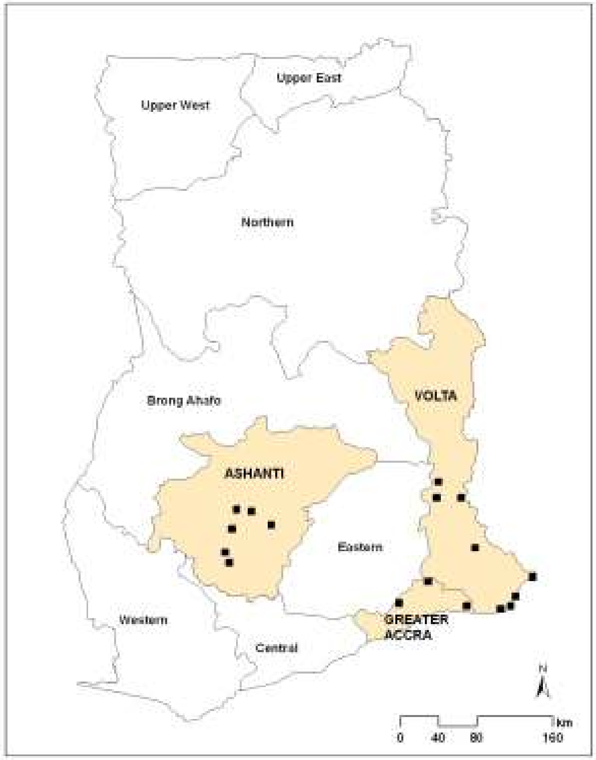

Figure 2: Study areas in Ashanti, Greater Accra, and Volta regions.

2. SOCIOECONOMIC AND DEMOGRAPHIC PROFILES OF GROUNDWATER IRRIGATORS AND OTHERS

Occupational profile of household heads and members

In UER, arable farming is the major livelihood strategy for all categories of farmers. However, there is a slight decrease in the proportion of farmers reporting arable farming as their major livelihood strategy among permanent shallow well and small reservoir irrigators. About three times as many household heads reported non-farm/off-farm activities as a major livelihood strategy among small reservoir irrigators as compared to other categories of farmers (Namara et al. 2010). Despite the prevalence of livestock in the UER, a low proportion of the sample farmers regarded livestock rearing as a major livelihood strategy. In fact, no household from the permanent shallow well and small reservoir irrigation categories reported livestock as a major livelihood strategy. Livestock keeping is a minor occupation for rainfed farmers and seasonal shallow well irrigators, whereas, non-farm/off-farm activities and fishing are considered important livelihood strategies for permanent and small reservoir irrigators.

For shallow groundwater users in Greater Accra and Volta regions, arable farming and non-farm/off-farm activities are almost equally important : 49.8% , 49.4%, and 0.8% of household members are engaged in farming, non-farm or off-farm activities , and livestock keeping and fishing respectively (N=255). Non-farm activities include bricklayer, carpenter, tailor, artisans, building contractor, *matron*, hair dresser, driver, seamstress, mechanic, petty trader, engineer, and pastor. Off-farm activities include crop marketing and crop processing.

Education and households demographic structures

IN UER, the proportion of female headed households in the purely rainfed household category is slightly higher than seasonal shallow well irrigators but significantly higher than the permanent shallow well and small reservoir household categories. The small reservoir irrigators have the highest levels of education. Moreover, permanent shallow well and small reservoir irrigating households have slightly fewer dependents and a larger number of working age members (Namara et al., 2010).

In the sample from Greater Accra and Volta, the illiteracy rate is low (3.9%). Eighty-nine percent attained junior secondary level schooling and 30.8% had college or university level training.

Asset and resources endowments

Water

The major water sources are rivers (30.9%), groundwater (30.6%), streams (19.3%), dugouts (14.9%), small reservoirs (2.2%), and lakes (2.1%). It is important to note that even purely rainfed farmers reported having access to surface water sources. Only 16.3% of the purely rainfed farmers reported no access to a water source.

Except in the Volta sample, rainfed farmers also have access to surface water sources. In the Volta case, none of the rainfed farmers reported access to water sources. For those who reported access to a water source, it is generally available within a distance of no more than a kilometer.

Farmers were allowed to subjectively assess the reliability of their water sources. The results indicated that farmers who own electric pumps had the highest reliability rating or perception, followed closely by petrol pump and bucket users. Canal users and rainfed farmers had the lowest degree of reliability perception about their water sources. The highest mean reliability rating was for groundwater followed by rivers. Small dams were judged as the least reliable source.

Regarding water use rights, the majority of respondents reported they can use water without getting permission from any authority. This is particularly so for groundwater. About 13% of the farmers with access to small reservoirs and dugouts reported needing permission from the chief or other responsible authority. The perception of farmers regarding water use rights diverge from official policies, which state that water resources in Ghana belong to the state.

Land: Farm size

There is no significant difference in land holding size among the different farm groups although petrol pump owners seem to have more cultivable land. Mean farm size is smaller in Greater Accra and highest in Volta region.

In Ashanti, Greater Accra, and Volta, 88.1% of the sample households reported having potential irrigable area out of which 8.3% have not yet started using it. The proportion of households who have not yet irrigated any part of their potential irrigable area varies from region to region. It is 20.9% in Ashanti, 0.8% in Greater Accra, and 1.7% in Volta. On average, 48% of the household members who reported having potential irrigable area have fully used their land. This value also varies from region to region.

In Ashanti, 26.7% of the sample households with potential irrigable land have fully developed their land. The corresponding values for Greater Accra and Volta are 61.6% and 48.6%, respectively. The mean potential irrigable area is about 1.44 ha. The highest mean potential irrigable area is reported from Volta (1.77 ha), and the lowest is recorded for Ashanti (1.14 ha). Mean potential irrigable area for Greater Accra is 1.49 ha.

On average, the size of per household of unused potential irrigable area is 54.25% of the reported mean potential irrigable area (1.44 ha). This value is 47.53% for Ashanti, 45% for Greater Accra and 42.53% for Volta.

The major reasons for not realizing the full potential of irrigable land are lack of finances for procuring equipment, followed by availability of water, and high cost of labor. The three regions generally face similar irrigation development constraints. However, some constraints are location specific. These include: water quality, lack of access to electricity and flood problems which are mainly applicable to the coastal areas of Greater Accra and Volta.

In UER, all the sample household categories have rainfed land and all categories (including the current purely rainfed farmers) have potential irrigable area. However, not all of the potential rainfed and irrigable area is put under cultivation, implying that water, not land, is the constraining factor in production.

The observed land tenure regime is complex. There are numerous modes of land transactions including inheritance, gift from friends or relatives or the land priest, rentals on a cash and share cropping basis, and purchases in rare cases, particularly for irrigated farming. The major source of land for both irrigated and rainfed farmers is inheritance. Rentals on a crop sharing basis are prevalent in rainfed farming areas, while rental on cash is more prevalent in irrigated farming areas. In the case of land rental, the duration of a contract ranges from a season (half a year) to 10 years. However, the majority of farmers (90.2%) said the contract only lasts for a year. Mean annual rental rate of land is about GHC 32.40 per acre, ranging from GHC 2.00 per acre to GHC 200.00 per acre.

Livestock
In UER, shallow groundwater irrigators tend to have more livestock even though the difference is not significant. However, shallow well irrigators have a significantly higher number of poultry, goats and pigs. Livestock holding size per household is significantly lower in Greater Accra and Volta regions.

3. AGRO-ECONOMIC ANALYSIS OF SHALLOW GROUNDWATER IRRIGATION

Technical description of groundwater irrigation systems
There are several versions of shallow groundwater irrigation systems observed in Ghana.

Seasonal shallow well irrigation systems: Seasonal shallow wells are usually used by farmers in areas in low-lying areas with high water tables, often along river banks, on riverbeds, in swampy areas or close to poorly functioning public or communal irrigation schemes such as reservoirs and dugouts. This system is widespread in several communities and is used during the dry season for vegetable farming by small-scale farmers. In the wet season, the river banks or riverbeds often flood, so most shallow wells are silted and areas under cultivation are water logged making use impossible. In the Upper East Region, the dry season shallow well irrigated areas are used during the wet season for cultivating staple crops such as maize, sorghum, and millet. Farmers re-fill the wells at the end of the dry season.

The wells are unlined and irregularly shaped, but are usually cylindrical. The depth of seasonal shallow wells ranges from one to five meters depending on the level of the water table and the technology used for lifting water. The diameter ranges between 70 cm to 100 cm but most are one meter in diameter. Simple tools (bar, axe, and hoe) are used for digging. A rope is tied to a bucket and the soil collected and pulled out of the well. This is continued until the water table is reached. Slopes are trimmed to specification when the water table is reached to enable the well to collect enough water. The number of wells constructed per unit cultivated area depends on depth and availability of water, planned size of irrigated area, the type of technology involved in lifting and distributing water, and the seepage rates from the surrounding ground into the well. A seasonal shallow well serves surrounding plots in a radius of up to 50 meters. Water is collected from the wells using different pumping technologies such as motorized pumps, hand pumps, treadle pumps, and rope and bucket systems. Motorized pumps are used particularly for wells sunk on the river beds. Field watering is also done manually mainly using the same buckets by literally pouring water on the field crops or using water hoses and pipes.

Permanent shallow well irrigation systems: These systems are developed closer to the homestead or even in the living compound. Permanent shallow wells can be lined with cement or left unlined. Farmers prefer lined wells but not all have the money to buy materials. The unlined wells are irregularly shaped and the depth ranges from one to 14 meters depending on groundwater level. The diameter ranges between from one to two meters. As with seasonal shallow wells, simple manual tools are used to construct the wells. Thus, the major cost components are human labor and cement for lining.

Shallow tube well irrigation systems: Shallow tube well irrigation systems are commonly found in the Volta and Greater Accra regions, specifically in the Keta Strip. They are individually owned and used for irrigation and domestic purposes. Land developed for this kind of irrigation is mostly family land. The irrigated area ranges from 0.21 to 0.81 hectares. The depth of a tube well ranges from six to nine meters and water is lifted mainly through a two-horsepower electric pump fixed near the well.

Borehole irrigation systems: Borehole irrigation systems abstract and use water from deep aquifers. There is a distinction is between shallow tube wells and boreholes depending on the nature of the recharging system and the depth to water. Boreholes are deeper and rely on aquifers for their recharge, while shallow tube wells rely on subsurface water for recharge. The extent of borehole irrigation systems is not yet determined but there are indications that the system has potential. The main limiting factors for expansion in Ghana may be the poor groundwater yield and the cost of development and maintenance. The deeper a well, the higher its construction costs and the cost per unit volume of water abstracted, irrespective of the type of water lifting device used. For these reasons, the use of groundwater for irrigation from deep aquifers has not been successful. There are indications that these systems are being used in Volta, Greater Accra, Central, and Northern regions of Ghana and to a lesser extent in Upper East and Upper West regions. Boreholes are usually sunk to withdraw water for domestic uses. Many boreholes developed for domestic uses have been abandoned because the quality of the water was not fit for drinking. These boreholes are being customized for irrigation (see Box 1).

Box 1: A borehole irrigation scheme
Pilot communal borehole irrigation systems were developed in the Upper East, Upper West, and Northern regions in 2000 under the MOFA's Village Infrastructure Project funded by the World Bank and Kreditanstalt Fur Wiederaufbau (KFW). A windmill pump and a 50 cubic meter ferrocement water storage facility were constructed at existing borehole sites, with a yield of about 1.50 l/min. When operational, the five meter Poldaw wind pump lifts water from a depth of about 80 meters into the storage reservoir. Water from the reservoir is allowed to flow freely by gravity.

Investment cost of shallow groundwater irrigation development
The investment costs of shallow groundwater irrigation typologies for UER are detailed in Table 3. In-field seasonal shallow wells are deeper and narrower than riverine shallow wells. Farmers drill on average about 2.4 riverine shallow wells to irrigate about 1.37 acres, while about 3.3 in-field seasonal shallow wells are dug to irrigate about 0.92 acres. Riverine shallow wells have better water yield than the in-field shallow wells. Farmers own on average about 1.3 permanent shallow wells irrigating about 0.51 acres of land.

The main elements of investment costs are well drilling, well lining and procurement of water lifting devices. Shallow tube wells cost more per constructed well. The water lifting devices employed are different for the shallow well types. Rope and bucket is the major water lifting device for in-field seasonal shallow wells and permanent shallow wells, while motorized pumps are employed to lift water from riverine shallow wells and tube wells. The service life of a motorized pump was estimated to be about 5.5 years. Rope and buckets systems last about 4.5 years. The mean cost of a motorized pump as reported by farmers was GHC 315.40.

Table 3. Investment costs of shallow well irrigation in UER.

Items	Riverine shallow well	In-field seasonal shallow well	Permanent shallow well	
			Lined	Unlined
Mean depth in meters	5.6	5.90	12.20	10.40
Drilling/lining labor in person-days per meter	0.94	0.94	4.20	4.30
Total drilling/lining labor cost	10.50	36.60	102.70	89.40
Material costs in GHC per meter	3.37	2.02	3.40	2.30
Total material costs of drilling	18.90	39.30	41.80	23.90
Total construction cost per well	29.40	23.00	144.50	113.4
Cost of lifting device per well	131.40	3.00	5.50	6.80
Total investment cost per well	160.80	26.00	150.0	120.00

There appears to be little difference in the depth of both types of wells. Even though riverine seasonal shallow wells are relatively less deep, they cost more to construct compared to the in-field seasonal shallow wells. More time is also required in the preparation of the riverine seasonal shallow wells. Nine of the 23 permanent shallow well irrigators owned permanent lined wells. The total start-up capital of a permanent lined well is about GHC 150.00 compared with GHC 120.00 for a permanent unlined well. Farmers claim that the cost could be much higher depending on the nature of the rock encountered during drilling.

The total investment cost per permanent shallow well is GHC 80.00 in Volta and GHC 154.00 in Greater Accra (Table 4). The permanent wells in Greater Accra and Volta tend to be shallower than in UER. The major cost components of shallow tube well development are (see Appendix 1):

- Tube well drilling including cost of PVC pipes and labor
- Pump installation including cost of pumps, foot valves and reducers
- Installation of pipe network including sprinklers and associated labor
- Electrical installation including cost of a meter, copper cable, and switch, and the construction of a meter house

The investment cost of tube well construction, excluding the costs for laying out a pipe network and sprinkler is shown in Table 4. Laying a pipe network cost about GHC 2348.00.

Table 4. Investment cost of shallow wells in Greater Accra and Volta.

	Mean depth in meters	Development cost per meter (GHC)		Total development cost per meter (GHC)	Development cost per well	Cost of lifting device	Total investment cost
Volta		Material	Labor				
Permanent shallow well	2.5	23.40	6.40	29.80	74.50	5.50	80.00
Shallow tube well	12.7	119.70	13.60	133.30	1199.70	343.65	1543.35
Greater Accra							
Permanent tube well	4.5	20.00	13.00	33.00	148.50	5.50	154.00
Shallow tube well	9.2	145.30	16.80	162.20	1492.20	343.65	1835.85

The costs are commensurate with the depth of the well. Labor constitutes a substantial part of the investment cost. Reliable estimates of the cost of drilling services in various parts of Ghana are difficult to find. Obuobie (2004) puts the average cost of drilling a 40 metre borehole at about USD 3,920. Local drillers in Keta District charge about GHC 50.00 (USD 36.00) for a shallow well of about 6 metres (Namara et al 2010).

Agronomic and on-farm water management practices and associated costs

Cropping pattern and agronomic practices

In UER, there were 171, 41 and 23 sample farmers representing in-field, reverine and permanent shallow wells. These farmers operated 247 fields with a total cultivated area of 227.2 acres. Three farmers operated both in-field and riverine shallow wells. The major crops grown during the 2008/2009 dry season included tomatoes (87%), peppers (9.5%) and other (3.5%). The other crops grown include onions, rice, okra, leafy vegetables and maize (Table 5). Thus tomatoes are the single most important crop grown under shallow groundwater irrigation. The major crop grown under permanent shallow well irrigation is peppers. A staple crop such as maize is also grown under permanent shallow well irrigation. For tomatoes, planting operations start in July and extend to January. About 81% of the fields were planted in the months from October to November. January, February, and March are the peak harvesting period for tomatoes. Harvesting is frequently carried out as a group. For peppers, August, September, and October are the busy planting months. The major harvesting operations are performed from December through April.

Table 5. Cropping pattern in UER.

Irrigation method	Tomatoes		Peppers		Other		Number of fields
	Area	%	Area	%	Area	%	
In-field	137.75	89.1	10.0	6.5	5.95	3.9	176
Riverine	58.25	94.3	2.5	4.0	1.0	1.6	48
Permanent	1.75	14.9	9.0	76.6	1.0	8.5	23
Total	197.75	87.0	21.5	9.5	7.95	3.5	

In Volta and Greater Accra vegetables are also the major crops grown under shallow groundwater irrigation, constituting 98.3% of the area. Maize is grown by some farmers as well and occupied 1.7% of the total area under shallow well irrigation during the dry season of 2008/2009. Farmers grow many crops on very small plots. Crops are often grown in a complex of associations and sequences. Some are intercropped. Maize is often grown for subsistence. Crops such as onions are preferred because they can be stored for several months without significant losses therefore ensuring an opportunity for farmers to get a high price.

The major agronomic and crop protection practices involved land preparation, fencing, planting, disease and pest control, weed control, soil fertility management and harvesting and threshing operations[1]. In UER, fencing is often necessary to protect irrigated fields from livestock and wildlife damage. Transplanting, dibbling, and broadcasting are three major methods of planting in order of significance.

On-farm water management practices

In UER, the on-farm water distribution or management methods employed by farmers are ridging (51%), basin/holing (39%), bed and furrow (6.8%), and other (3.2%). There is a significant difference in the on-farm water management systems employed by the different shallow groundwater irrigation typologies. The majority of riverine shallow well irrigated fields adopted ridging (95.7% of the fields). Whereas 92.9% of the fields under in-field seasonal shallow well irrigation employed the basin/hole and ridging systems. All of the permanent shallow well irrigators constructed basin/hole and bed and furrow structures. The system of on-farm water management employed is dictated by the quantity of available water in the well and partly also by the nature of the crop. The basin/hole system is the most water efficient and is practiced on 46.2% of the in-field shallow well irrigation fields and 56.5% of permanent shallow well irrigated fields. The water yield of in-field shallow wells is inferior to the riverine shallow wells and water from permanent shallow wells is used for multiple purposes. For shallow tube wells, the major on-farm water management system is the sprinkler system. To lay out a sprinkler systems on a hectare of land cost GHC 2,348.00.

Most farmers do not irrigate their fields during plowing. For in-field shallow groundwater and riverine shallow well irrigators, 1 to 3 irrigations are done during plowing with one irrigation the most common practice. Permanent shallow well irrigators tend to give more

[1] For details of these practices please see Namara et al. 2010

irrigation during plowing as compared to the other groups. On average, farmers practice irrigation for about 12 weeks, each week providing about three irrigations. All of the riverine shallow well irrigators used motorized pumps to lift water, while almost all of the shallow tube well farmers used electric pumps.

Economics of shallow groundwater irrigation

The profitability of irrigated vegetable cultivation under the three shallow groundwater irrigation systems in UER is summarized in Table 6. Labor constitutes a significant proportion of the total costs. Fixed costs constitute a small part of the total cost of production and range from 1.3% to 11%. For in-field shallow well irrigators, the fixed cost is especially low because farmers perform drilling every season and use only rudimentary technologies for land preparation, land levelling, and water lifting. For riverine shallow groundwater users and permanent shallow wells, the fixed costs are higher because for the former farmers use motorized pumps for water lifting and for the latter the drilled wells are deeper and are used for several years. Thus, shallow groundwater-based irrigation is suitable for capital constrained and labor abundant farmers of Upper East Ghana. The gross margin[2] (or income above variable costs) was negative for peppers under in-field shallow well irrigation and tomatoes under permanent shallow well irrigation. However, when the opportunity cost of labor is deducted from the variable costs (see the "returns to assets and labor" row in Table 6.), the benefits realized from irrigated tomatoes and peppers become not only positive but quite significant. The highest benefit was recorded for tomato production under riverine shallow well irrigation. The consideration for fixed costs has little bearing on the expected benefit values. The expected benefit is influenced to a greater extent by the magnitude of the opportunity cost of labor.

Table 6. Profitability analysis.

Items	In-field seasonal shallow well		Riverine seasonal shallow well		Permanent shallow well	
	Tomatoes	Peppers	Tomatoes	Peppers	Tomatoes	Peppers
Gross income (GHC[3])	859.00	989.00	1478.0	722.00	348.00	927.00
Variable costs (GHC**)**						
Fertilizer	110.70	208.40	215.80	0.00	24.10	169.80
Well drilling	40.60	40.60	34.80	34.80	0.00	0.00
Fencing	23.70	22.70	40.00	40.00	4.00	4.00
Seed	33.50	20.50	33.50	20.50	14.0	14.00
Insecticide	19.30	39.50	26.00	0.0	13.4	16.8
Fuel	0.0	0.00	35.80	35.80	0.00	0.00
Labor	297.50	564.70	191.60	216.60	451.20	531.00

[2] This analysis considers the opportunity cost of labor at about 2GH₵ per man-day

[3] IUS$=GHc1.5 and the calculations are on Acre basis

Capital cost	76.40	99.00	124.90	41.00	17.90	54.00
Total variable cost	601.70	995.40	702.40	388.70	524.60	789.60
Gross margin	257.40	-6.40	775.6	333.2	-176.6	137.40
Returns to assets and labor	554.9	558.30	967.20	549.80	274.60	668.40
Fixed cost (GHC)	7.90	7.90	48.20	48.20	48.70	48.70
Total cost (GHC)	609.60	1003.30	750.60	436.90	573.30	838.30
Returns to land and management	249.40	-14.30	727.40	285.10	-225.30	88.70
Total labor per acre (person-days)	148.75	282.37	95.81	108.31	225.60	265.50

The gross margin for tube well irrigation in Greater Accra and Volta by seasons is summarized in Table 7. The gross margin figures are significantly higher than those recorded in UER for other types of shallow groundwater irrigation. Wet season gross margins are by far higher than the dry season gross margins.

Table 7. Mean gross margin for tube well shallow groundwater irrigation in Greater Accra and Volta.

Season	Gross margin(USD/ha)	N
Dry season	2,190.70	93
Wet season	4,421.30	76
Mean	3193.80	169

4. Socioeconomic impacts of shallow groundwater irrigation

Employment and value added

In the Upper East Region, the three months of dry season irrigation using shallow groundwater have created additional labor demand estimated at 359,511 person-days, which is 214 Full Time Equivalent[4] (FTE) per year (Table 8). The total contribution of shallow groundwater irrigation to the economy of the 35 communities in the White Volta Basin is 1.62 million GHC (or about 1.2 million USD).

Table 8. Labor demand and economic contribution of shallow groundwater irrigation in UER.

Irrigation typology	Labor (person-days)	Value added in GHC
In-field seasonal shallow well	240,889	903,214.30
Riverine seasonal shallow well	50,800	543,158.01
Permanent shallow wells	67,822	170,197.01

[4] One FTE per year is equivalent to 1680 hours of work per year or 35 hours per week

Poverty and inequality

In UER, income disparity among sample farmers seems not to be that serious (Namara et al. 2010). Income inequality is least among in-field seasonal shallow well irrigators and higher among riverine shallow well and small reservoir irrigators. On average, 57% of the sample farmers are poor, which is above the national average for poverty incidence in Ghana. This finding confirms the general understanding that poverty is severe in Northern Ghana. The poverty incidence among sample farmers with access to shallow groundwater irrigation (or irrigation) is lower compared to purely rainfed farmers. The poverty gap, which is a measure of depth of poverty or the mean consumption shortfall from the poverty line, is lower among farming households with access to irrigation but the difference is not significant (Namara et al. 2010). The overall mean poverty gap value is 0.15, which means that to lift the poor out of poverty, their current consumption level has to be increased by 15%.Thus, access to shallow groundwater irrigation may have contributed to poverty reduction.

The overwhelming majority of the current practitioners of shallow tube well irrigation belong to the well off portion of the farming population (Fig. 3). Access to shallow tube wells might have contributed to improvements in the socioeconomic status of these practitioners.

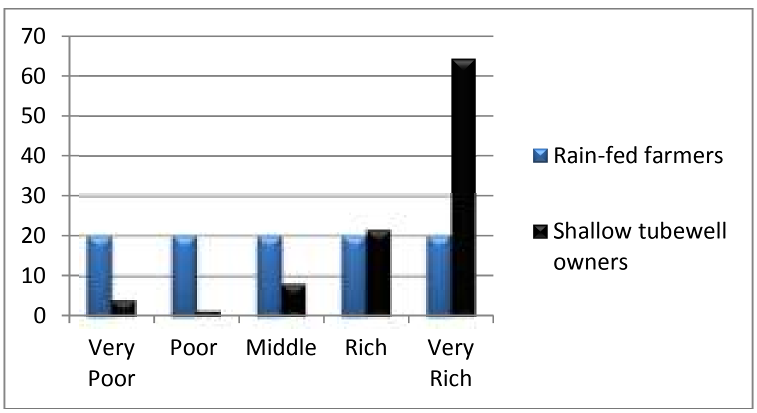

Figure 3. Socioeconomic status of shallow tube well owners versus rainfed farmers.

Food security

Using the data collected from the UER, the food security impact of access to shallow groundwater irrigation is analyzed. We use months of inadequate food provisioning and household dietary diversity indices as conceptualized by Swindale and Bilinsky (2005) to compare the food security situation of households with access and without access to shallow groundwater irrigation.

In UER, the majority of farmers, irrespective of whether they had access to irrigation, reported having food shortages during the last 12 months from the date of the interview. Only 1.2% of the farmers reported having adequate food all year round. A farm household can run out of food for a maximum of eight months. However, in any given month the percentage of farmers reporting food shortages is higher for purely rainfed farmers compared to farmers practicing irrigation of one sort or another (Fig. 4).

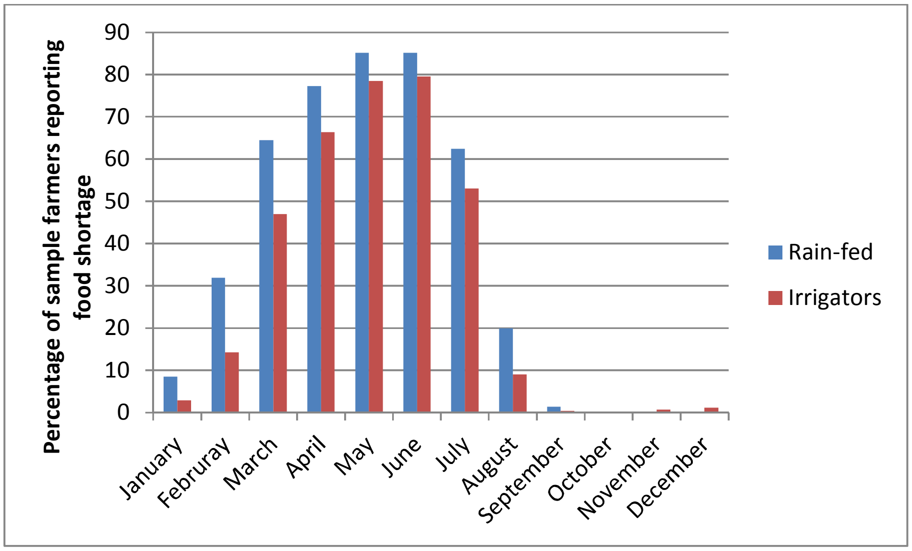

Figure 4. Percentage of farmers reporting food shortages differentiated by month and farming system.

The relationship between irrigation typology and food security is depicted in Figure 5. Generally, the mean number of food insecure months is higher among purely rainfed farmers closely followed by seasonal shallow well irrigators. The reported mean food insecure months are low for farmers practicing permanent shallow well and small reservoir irrigation.

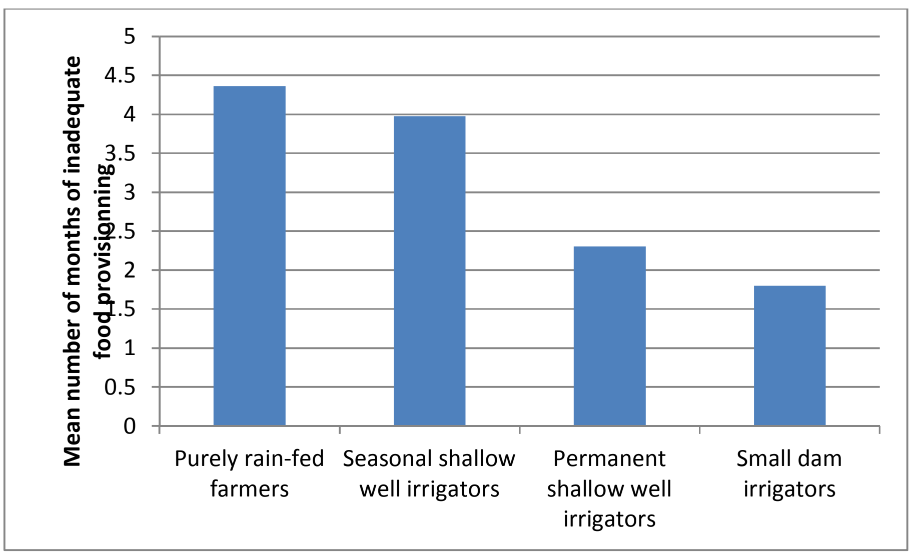

Figure 5. Number of months of inadequate food provisioning.

Food availability as measured by months of inadequate food provisioning is not enough to assess household access to food. It must be complemented by an assessment of household dietary diversity, which is the number of different food groups consumed over a given reference period, usually during the last 24 hours. A more diversified diet is an important outcome in and of itself and is associated with a number of indicators such as birth weight, child anthropometric status, and improved hemoglobin concentrations, caloric and protein adequacy, percentage of protein from animal sources (high quality protein), and household income.

Following Swindale and Bilinsky (2005), the sample farmers were asked if any of the following 12 food groups were consumed during the last 24 hours: cereals, roots and tubers, vegetables, fruits, meat (poultry, offal), eggs, fish and seafood, pulses/legumes/nuts, milk and milk products, oil/fats, sugar/honey and miscellaneous. Data were collected by asking the respondent a series of yes/no questions in relation to the identified food groups. These questions were administered to the person who is responsible for food preparation. The questions refer to the household as a whole, not to any single member of the household. The dietary diversity score ranges from 0 to 12. In general, any increase in household dietary diversity reflects an improvement in the household diet. Knowing that household members consume, for example, an average of four different food groups implies that their diets offer some diversity in both macro and micronutrients. This is a more meaningful indicator than knowing that household members consume four different foods, which might all be cereals.

The overall mean household dietary diversity score is 6.4. The mean household dietary diversity score for purely rainfed farmers was 6.3, while the corresponding value for those with access to any type of irrigation is 6.5. The difference is not statistically significant. However, there is a difference in household dietary diversity scores between different categories of farmers defined by access to irrigation (Fig. 6). Seasonal shallow well irrigators had the highest household dietary diversity scores, implying that their diets offer some diversity in both macro- and micronutrients.

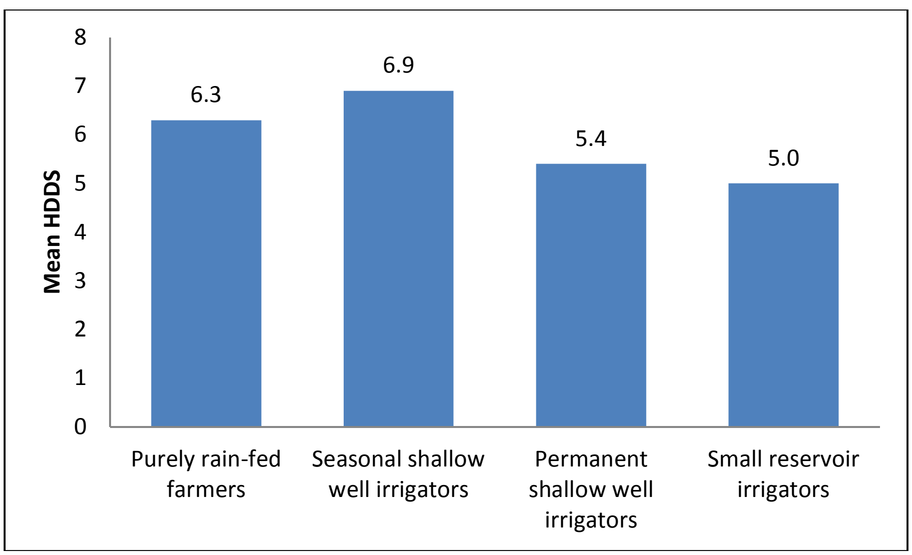

Figure 6. Comparison of mean household dietary diversity scores.

Households with access to permanent shallow well and small reservoir irrigation had lower household dietary diversity scores even than the purely rainfed farmers. Even though permanent shallow well and small reservoir irrigators have registered better food availability as indicated by months of inadequate food provisioning, they had the lowest dietary diversity. In summary, access to shallow well and other forms of irrigation has contributed to a reduction in food insecurity, even though it does not eliminate it.

5. CONSTRAINTS TO SHALLOW GROUNDWATER USE FOR AGRICULTURE

Groundwater irrigation provides potential employment opportunities, particularly during the long dry season in the northern savannah zones. However, full realization of the economic potential of groundwater faces challenges.

Institutional issues: Land tenure security is a major concern. Because of land tenure insecurity, many farmers have to endure the drudgery of digging and refilling wells every season. Many farmers work on plots leased or given to them for free or at little cost. Therefore, they do not enjoy the assurance that they will be using the same plot of land next season.

Technical issues: Lack of adequate knowledge of the potential of the resource and affordable and efficient technology and methods for drilling wells are considered major limiting factors. Currently, farmers rely on their own judgement and trial and error methods for locating wells.

Marketing: Groundwater irrigators are necessarily market oriented by virtue of the nature of crops they cultivate. They consume a smaller share of what is produced. Most of the outputs are perishable, requiring special storage and transportation facilities. Temporal and spatial price variability is high, and there are limited marketing channels or market participants (Namara et al. 2011). The paucity of alternative marketing channels and market participants allows few buyers (e.g., market women) to bid the price down. Consequently, crops are sold directly from the field as farmers have no storage facilities to keep freshly harvested vegetables. Purchases are usually on credit. The transportation cost is high due to the poor road network. The ratio of high price per unit received from the sale of vegetable crops to corresponding low price received for the quantity within a season is as high as 700%.

Biophysical: Dry season vegetable production is also severely constrained by the occurrence of pests and diseases, which cause significant yield loss or forces farmers to purchase expensive chemicals to protect their crops. The notable pests and diseases are nematodes, root rot, leaf curl, and aphids. Birds and fowl also destroy crop, since dry season crops are the main food items available during the dry season.

Livestock/dry season crop cultivation interface: A major problem in the dry season is the presence of livestock that frequently destroy crops. Farmers would like to fence their plots. Fencing can be a major cost item, particularly in Northern Ghana where livestock rearing is an important household activity.

Limited access to inputs and technologies: The high cost of inputs such as fertilizers, pesticides, herbicides, and improved seeds contributes to financial loss or significant reduction in the profit margins of farmers, thus reducing farmers' incentives. Most groundwater irrigated crops do not qualify for the government's current fertilizer subsidy policy. For instance, certified shallot seeds are not easily available in Ghana. There is also a paucity of affordable land preparation technologies. Most Ghanaian farmers have little experience in cheaper alternative plowing techniques such as bullock traction.

The availability of modern and efficient water lifting technologies and affordable well drilling technologies or services is also a constraint to the development of groundwater irrigation. For those in use, farmers lack the skill for maintenance and operation. Energy for lifting and distributing water is also a problem. The price of petrol and diesel are high.

Labor availability or drudgery: In situations where water is manually lifted and distributed, farming becomes labor intensive. High frequency of irrigation in sandy coastal areas also contributes to high labor demand.

Limited availability of credit facilities: Credit services are limited for developing wells, acquiring water lifting devices and financing expenses for crop production inputs. If available, the terms of credit are high.

Extension support: Extension services in the irrigation sector in general and in groundwater irrigation sector in particular are poor. Farmers need agronomic advice to find appropriate seeds and agrochemicals. Farmers claim that that extension services are not regularly available. There is at present no advice available to farmers on the amount of water or irrigation schedule that they should use for a particular crop.

6. CONCLUSIONS

The agricultural use of groundwater is not sufficiently addressed in Ghana's water and irrigation policies. This is largely true for most of Sub-Saharan African countries.

Knowledge about Ghana's groundwater resource is scarce. The limited available information paints a pessimistic picture of the resource potential, often mentioning challenges such as resource depletion, low yield, and poor quality. Despite the official pessimism, smallholders have developed shallow groundwater-based irrigation systems in many regions including the Upper East Region in response to population pressure, the availability of road infrastructure, and cross-country farmer-to-farmer knowledge transfer.

Farmers have developed complex but water efficient and labor intensive on-farm water management and agronomic practices which reflect the differential relative resource scarcities during the long dry season. During the dry season land and labor are relatively abundant but water is the limiting factor in production.

The investment cost of developing shallow groundwater for irrigation is low. Except for riverine shallow wells, which involve buying motorized pumps, labor comprises the largest share of the total investment cost. In fact, in-field shallow well development entails little fixed cost. The high labor demand and low initial capital requirement of the current shallow groundwater development technology is compatible with the socioeconomic circumstances of the farming communities in the three northern regions, particularly during the dry season. Labor constitutes a significant proportion of the cost of production. The fixed cost of production is low, constituting less than 11% of the total cost. This is because farmers largely employ rudimentary technologies that are available at extremely low prices or can be made by the farmers themselves.

Tomatoes and peppers are the two major crops. Many other crops are also cultivated including onion, okra, leafy vegetables, rice and maize, often in complex associations and sequences.
The type, rate and combination of chemical fertilizers applied by farmers are not based on sound experimental research results or research based extension advice. It is usually based on farmers own judgements or extrapolations of extension recommendations for rainfed crops. Similarly, farmers lack advice on type, rate of application and the safety precautions required in calibrating and applying pesticides.

The cultivation of tomatoes and peppers under shallow groundwater irrigation is generally profitable, particularly when the value of labor involved in the cultivation process is not considered. Furthermore, the economics of crop cultivation under shallow groundwater irrigation is influenced by the extreme volatility of vegetable crop prices, particularly that of tomatoes and the various production risks. However, the opportunity cost of labor is the key for the sustainability of the current shallow groundwater irrigation economy in the White Volta Basin.

The total estimated shallow groundwater irrigated area in the White Volta Basin during the 2008/2009 dry season was 2262.6 acres of which 1,475 acre was developed using in-field seasonal shallow wells, 526.3 acres using riverine seasonal shallow wells, and 261.3 acres using permanent shallow wells. In Keta District in the Volta region alone there were 34,263 wells irrigating 2,597.5 acres (GIDA/MOFA 2008).

These irrigation systems have:

- created jobs, particularly for young people during the dry season, thereby reducing rural-urban and north-south distress migration;
- significantly contributed to the economy of the communities involved; the total value addition of shallow groundwater irrigation was estimated to be USD 1.2 million in just 3 to 4 months;
- contributed to poverty reduction but have not eliminated it; and
- enhanced the food security status of practitioners.

7. Recommendations

- Provision of explicit policy support to the shallow groundwater irrigation sector.
- Provision of special consideration for shallow groundwater irrigation in the country's rural energy policy and planning.
- Improve knowledge on groundwater potential and distribution in the country.
- Develop a map of shallow groundwater distribution in Ghana in an easy to comprehend mode to support investment decisions by a wide spectrum of potential users including smallholder farmers and unemployed youth.

- Provide more institutional support to the sector by setting up a body or a department with a mandate to oversee the development of the agricultural use of groundwater.
- Provide land tenure security through innovative institutional arrangements.
- Improve the availability of affordable drilling services.
- Improve farmers' access to pumping and on-farm water application technologies including sprinklers and drip systems.
- Provision of agronomic research support.
- Provision of on-farm water management research support.
- Train farmers in safety precautions regarding the handling of agrochemicals.
- Consider specialist extension service to farmers tailored to the complex managerial needs of groundwater-based irrigation.
- Consider improving the supply of complementary inputs such as fertilizers, improved seeds and other relevant technologies during the off-season.
- Improve output marketing and value additions in the sector.

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Appendix 1: Cost Details of Typical One Hectare Sprinkler Irrigation Scheme at Keta.

Phase	Item No.	Component	Quantity	Unit Cost (GH¢)	Total Cost (GH¢)
Tube Well Development	1.1	6" x 10' PVC Pipe	3	9.00	27.00
	1.2	4" x 20' PVC Pipe	2	8.00	16.00
	1.3	Labor for Tube well	1	50.00	50.00
	subtotal				**93.00**
Pump Installation	2.1	Foot Valve	1	13.00	13.00
	2.2	4"x2" Reducer	1	5.00	5.00
	2.3	Pump Installation	1	25.00	25.00
	2.4	Pump (Pedrollo /Cear) Horse Power	1	450.00	450.00
	subtotal				**493.00**
Pipe Network	3.1	2" x 20' PVC pipe	128	9.00	1152.00
	3.2	1" x 20' PVC	16	6.00	96.00
	3.3	2" T Joint Socket	56	2.50	140.00
	3.4	2" x 1" Reducer	64	1.50	96.00
	3.5	2" L Joint Socket	8	1.50	12.00
	3.6	1" x 25m Water Hose	5	30.00	150.00
	3.7	Sprinkler	24	15.00	360.00
	3.8	Fancet 1"	64	1.50	96.00
	3.9	Valve Socket 1"	64	1.50	96.00
	3.10	Labor	1	150.00	150.00
	subtotal				**2348.00**
Electrical Installation (varies with site)	4.1	Meter House	1	20.00	20.00
	4.2	Meter	1	200	200.00
	4.3	4mm Copper Cable (80m)	2	45	90.00
	4.4	2.5mm Copper Cable (80m)	2	37	74.00
	4.5	Switch	1	5	5.00
	subtotal				**389.00**
	TOTAL				**3323.00**