RESEARCH
REPORT

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Treadle Pump Irrigation and Poverty in Ghana

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International Water Management Institute

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Cover photograph shows two farmers in West Africa, one using a treadle pump and the other collecting the pumped water (photo credit: IWMI-Ghana).

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Contents

Acronyms

ANPIP	Agence Nigerienne de Promotion de l'irrigation Privee (Nigérien Agency for the Promotion of Private Irrigation)
EW	Enterprise Works
EWW	Enterprise Works Worldwide
IDE	International Development Enterprises
NGO	Nongovernmental organization
TP	Treadle pump

Summary

Treadle pump (TP) technology has been promoted by Enterprise Works Worldwide (EWW) in West Africa as an alternative to the traditional rope and bucket irrigation that is necessary to overcome the challenge of uncertain and inadequate rainfall for agricultural production. The aim is to improve output, increase incomes and reduce poverty among rural farm households. This study examines the strategies used for dissemination of the TP and the dynamics of its adoption and impacts, with a special focus on poverty reduction. The data source for the study is a primary survey involving interviews with adopters and non-adopters of TP in the Volta and Ashanti regions of Ghana. The results of the study reveal that time and labor savings for irrigation, increased size of irrigated areas and lack of fuel requirements are the attractive features of the TP for those who adopt it. Almost all the TP adopters in the research sample were men. About 26 percent of the adopters achieved an increase in irrigated area; all saved time spent on irrigation and increased net farm income. The productivity of land and labor increased, while the welfare of adopters improved. The study demonstrates that adoption of TP reduces poverty. A positive impact on human capital was realized as incomes were used to pay for children's schooling and for health care. Some farmers, however, stopped the use of the TP, mostly because it broke down and could not be used over large extents of land. Also, about 10 percent of the adopters were able to shift to motorized pumping. It is recommended that a variety of improvements in design, dissemination and capacity might improve the impact of TP technology in West Africa. Increased collaboration with local institutions such as extension services could make the TP reach the farmers better. In this regard, a long-term program would be more effective than short-term projects. Design improvements should be undertaken to ease pedaling so as to encourage the uptake of the TP by women and enhance their chance of benefiting directly from it. The introduction of after-sales service and training of farmers on minor repairs will improve the continuous use and sustainability of the TP.

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Introduction

Agricultural production in sub-Saharan Africa is adversely affected by erratic rainfall events within and between years. This has led to poor yields, low productivity, food insecurity and poverty within the farming population, thus emphasizing the need for irrigation in the region. The traditional system comprises the use of ropes and buckets to lift and distribute water from shallow open wells or watering cans to lift water from streams. Although the low capital requirement of these traditional technologies makes them advantageous and affordable, their low delivery capacity and labor-intensive nature make them highly unfavorable (Kamara et al. 2004). Improved water-lifting technologies, with relatively high efficiencies such as motorized pumps, have been tried and found suitable for, mainly, better-off farmers. For small-scale farmers, who usually irrigate relatively small plots of land and operate on a relatively small capital, such technologies are unaffordable. This lack of simple, affordable and well-adapted water development technologies, suitable for the production conditions and needs of smallholder farmers in sub-Saharan Africa, is a serious handicap to efforts for achieving food security on the continent (Hyman et al. 1995; Brabben and Kay 2000).

Today, a substantial variety of low-cost, affordable water management options exist. The use of the TP for irrigation is widely acknowledged as one such option (EW 2004). The aim of this study is to investigate the strategies used for the dissemination of the treadle pump (TP) and dynamics of its adoption and impacts, with a special focus on poverty reduction. The TP is considered suitable and easily adaptable to African production conditions. It is a low-lift, high-capacity, human-powered water lifting device designed to overcome common obstacles to irrigation by resource-poor farmers. It can lift 5-7 cubic meters of water per hour from wells and bore holes from a depth of 7 meters (m), as well as from surface water sources such as lakes and rivers. Box 1 presents a description of a common TP introduced to West Africa. Manufacturing, marketing and distribution campaigns of the TP are carried out through development organizations like KickStart[1] in East Africa and Enterprise Works Worldwide (EWW)[2] in West Africa.

The economic impacts of TP adoption are well documented in the West African context. In Mali, for example, adopters have been able to increase their incomes from $444[3] per farm before using the pump to $801 per farm after using it (EW 2004). In Burkina Faso, a survey of farmers showed that irrigated area increased by 140 percent after the adoption of pumps (EWW 2003). In Niger, within a period of 6 years, market gardeners were able to increase their net farm incomes sixfold from $185 to $1,163 after adoption (ANPIP 2005). Data from Niger also showed a net increase in the number of persons per TP, indicating increased employment opportunities created by the use of pumps. These results from West Africa are similar to TP impacts reported from South Asia including eastern India, Nepal Terai and Bangladesh (Shah et al. 2000). These impacts are in line with the notion that irrigation technology leads to increases in total farm output and farm incomes (Lipton et al. 2003).

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[1] KickStart was formerly known as AproTech.

[2] Enterprise Works is an international NGO known formerly as AT International.

[3] In this report, $=US$.

Box 1. TP types and characteristics introduced by EWW in West Africa.

There are two types of TPs: those that lift water from a lower level to the height of the pump, commonly called suction pumps and those that lift water from a lower level to a height greater than the height of the pump, known as pressure pumps. In all forms, water is pumped by two direct-displacement pistons, which are operated alternately by the stepping motion of the user. TPs have two significant advantages over motorized pumps for irrigation of agricultural land of less than one hectare. They are considerably less expensive than motorized pumps regardless of the type, and also cost much less to operate, because they require no fuel and only limited repair and maintenance costs.

The TP also possesses a number of features which sets it apart from other nonmotorized irrigation pumps. First, its water lifting capacity of 5-7 cubic meters per hour (m^3/h) meets the irrigation requirements of most African farmers, the majority of whom cultivate less than one hectare of land. Second, because the TP employs the user's body weight and leg muscles in walking motion, use of the pump can be sustained for extended periods of time without excessive fatigue. Operating the TP is much less tiring than operating other manual pumps that utilize the upper body and relatively weak arm muscles. Third, the TP is fabricated entirely from locally available materials and can be manufactured using welding equipment and simple hand tools in the metal workshops commonly found in Africa.

TPs available in West Africa:

1. *The Bangladesh standard pump* can lift water from a depth of 8 m, and water is discharged at the pump level. The pump can be operated by one or two persons. The discharge varies between 5 and 9 m^3/h depending on the number and size of operators and the depth to the water. Its approximate cost in Niger is about $120.
2. *The Bangladesh large diameter pump* can lift water from a maximum depth of 2.5 m. It can be operated by one or two persons. The discharge is 12 m^3/h depending on the number and size of operators and the depth to the water. Its approximate cost in Niger is about $180.
3. *The compact suction-pressure pump (Gajera)* can lift water from a depth of 8 m and supply it under pressure over a distance of 150 m on flat terrain. It can also raise water to 7 m above the level of the pump. The maximum discharge varies between 4 and 5 m^3/h. It is operated by only one person. Its approximate cost in Niger is $70-$80.
4. *The compact suction pump (Gajera)* can lift water from a maximum depth of 8 m and discharge it at the pump level. The pump is lightweight and can be transported easily. It is operated by one person but its operation is easier than that of other TPs. Its approximate cost in Niger is $70-$80.
5. *The deep well pump* can lift water from depths of up to 15 m. It was developed for zones where the water table depth exceeds 8 m. The pump is heavy and therefore it is semipermanently installed in the well. The maximum discharge is between 3 and 4.5 m^3/h. Its approximate cost is $240.
6. *The suction-pressure pump (large diameter)* can lift water from a depth of 2.5 m and supply it under pressure over a distance of 100 m of flat terrain. It can also lift water 4 m above the level of the pump. It can be operated by one or two persons; its maximum discharge is 10 m^3/h and its approximate cost is $180.

Facilitating Access: The Role of Enterprise Works

Enterprise Works (EW) is an international NGO that applies its expertise in technology development, adaptation and commercialization in West Africa. EW has facilitated access to low-cost and high-performance irrigation equipment (particularly TPs) for low-income farmers in many West African countries. The involvement of EW in the promotion of TPs in West Africa began in the early 1990s. By 1995, dissemination had already begun in Senegal and Mali, and by the end of 1996, about 1,900 and 600 pumps, respectively, had been produced in the two countries. EW pumps are based on the Bangladesh model[4] but modified for pressure delivery. For example, the pumps used in Niger are similar to the Bielenberg pump designed from the Bangladesh TP model but modified to suit local needs.

The main objectives of the EW approach to technology dissemination are to:

- increase local capacity for manufacture
- use a business model of demand creation based on creative advertising techniques
- promote sustainability by discouraging subsidies and empowering farmers to maintain their pumps

According to Naugle (2000) there are five main issues considered relevant in the EW philosophy of technology promotion to enhance commercialization within the adopting population. These issues include:

- production as close as possible to the end user
- affordability for the buyers
- profitability for the producers
- reliability of the technology to enhance customer satisfaction
- provision of after-sales service to help buyers familiarize themselves with the product, and to overcome preliminary problems associated with the adoption of new technologies

EW has a strategy that provides initial start-up support such as training, tools, marketing strategy and after-sales care to enhance customer satisfaction and sustainability.

The manufacturing of TPs is placed in the hands of local workshop owners. In Niger, the training of these manufacturers in their own workshops is done over a period of 10 days. Three pumps are made at the initial training and after the manufacturer has shown proficiency with one model by making ten or more pumps, training for other models can be made available, usually on demand. Thereafter, manufacturers are taken to farm sites to carry out demonstrations and to develop direct contact with farmers. Initial sales of the first three pumps are strived at to encourage manufacturers to appreciate the market potential of the pump. Manufacturers are encouraged to use hire-purchase agreements with farmers, especially in areas where the pump is not well known. A similar strategy is employed in other West African countries.

EW promotes the technologies to farmers in the irrigated horticultural subsector by utilizing radio and television advertising, public, on-site and market demonstrations, farmer-assisted sales and other techniques. In Niger, publicity is an important part of marketing involving a multimedia publicity campaign. A local name, *Niyya da Kokari* ('willingness and courage'), understood in the three main languages, was given to the pump. A song was composed by a local acting troupe extolling the virtues of the pump and publicizing its name. This publicity included radio and television commercials, and the visual impact

[4]Bangladesh pumps were the first TPs to be used in West Africa.

of seeing the advertisement does create a positive impression (Kay and Brabben 2000). A copy of the manuals on an audiocassette tape in local languages is supplied along with each pump sold. In Ghana, the TP was branded as the SOKA pump, and EW, in the initial stages, offered marketing assistance through mass media advertisements and on-farm demonstrations to create awareness. Once the pumps become popular and sales start to increase, manufacturers are linked up with designated sales agents from whom farmers buy pumps directly. For farmer-assisted sales, an early adopter is encouraged to promote the technology among his or her neighbors in return for a sales commission from the manufacturer.

EW encourages farmers to purchase the pump at the fully unsubsidized price directly from local manufacturers or sales agents without the intervention of the project. It is thought that this will help ensure sustainability of the program, by building a viable local market that does not depend on the project or subsidies. In addition, EW ensures that spare parts and knowledge of repair accompany the pumps. All pumps are supplied with one set of spare pump leathers, a wrench for opening the pump body and adjusting the pistons, and a 6 m length of 50 millimeter (mm) thin-wall PVC pipe for the suction side of the pump. The farmer is visited three times after purchase by a field agent and/or a representative of the manufacturer. The viability of this strategy in West Africa is not clear however, as evidenced by experience in Niger where sales steadily increased between 1997 and 2001 when sales were subsidized by the government, but plummeted in 2002, especially among female farmers, when subsidies were withdrawn (ANPIP 2005).

EW TP programs in West Africa are, or have been, active in Senegal, Mali, Niger, Cote d'Ivoire, Burkina Faso, Ghana and Benin. Approximately 8,500 pumps were sold across West Africa with overall economic benefits estimated at $20.9 million (table 1). These sales are, however, far below those reported for South Asia by International Development Enterprises (IDE), a US-based NGO that uses a similar business and market development approach. IDE reported sales in Bangladesh of 1.3 million pumps since the mid-1980s, the bulk of sales occurring during a 3-year period in the mid-1990s. An additional 200,000 pumps were sold in eastern India and 200,000 pumps in Nepal (Shah et al. 2000).

TABLE 1.
Summary of EW sales across West Africa.*

Country	Period of activity	Number of pumps sold	@ net annual income per pump ($)	Total economic benefits (million $)
Senegal	1990 – 2001	3,048	584	8.9
Mali	1995 – 2001	2,311	542	6.3
Niger	1997 – 2001	1,161	289	1.9
Benin	1998 – 2001	771	479	1.8
Burkina Faso	2000 – 2001	504	306	0.8
Cote d'Ivoire	2000 – 2001	495	479	1.2
Ghana	2002 – 2003	630	822 [a]	Na
West Africa	1990 – 2003	8,469 [b]	349 [b]	20.9 [b]

Source: EWW 2003.

Notes: [a] For vegetable growers only in 2003; [b] Excluding Ghana; * Estimated life span of the pump is 5 year; Na = not available.

Research Questions and Methodology

TP technology is widely believed to be a pro-poor, poverty-alleviating technology due to its demonstrated potential for low-cost irrigation and suitability for small-scale farming. Many important questions remain unanswered, however, with respect to the links between the adoption of TP and poverty status of small-scale farmers. First, it is widely believed that the technology self-selects the poor, has poverty reducing impacts and is gender-neutral. Are these assumptions true for West Africa? Second, how effective is the technology dissemination approach adopted by development organizations in the region with regard to the development of local capacity for manufacture, service and awareness required for sustainability of the technology? Third, what social and economic factors determine the adoption of TP and its discontinuance?

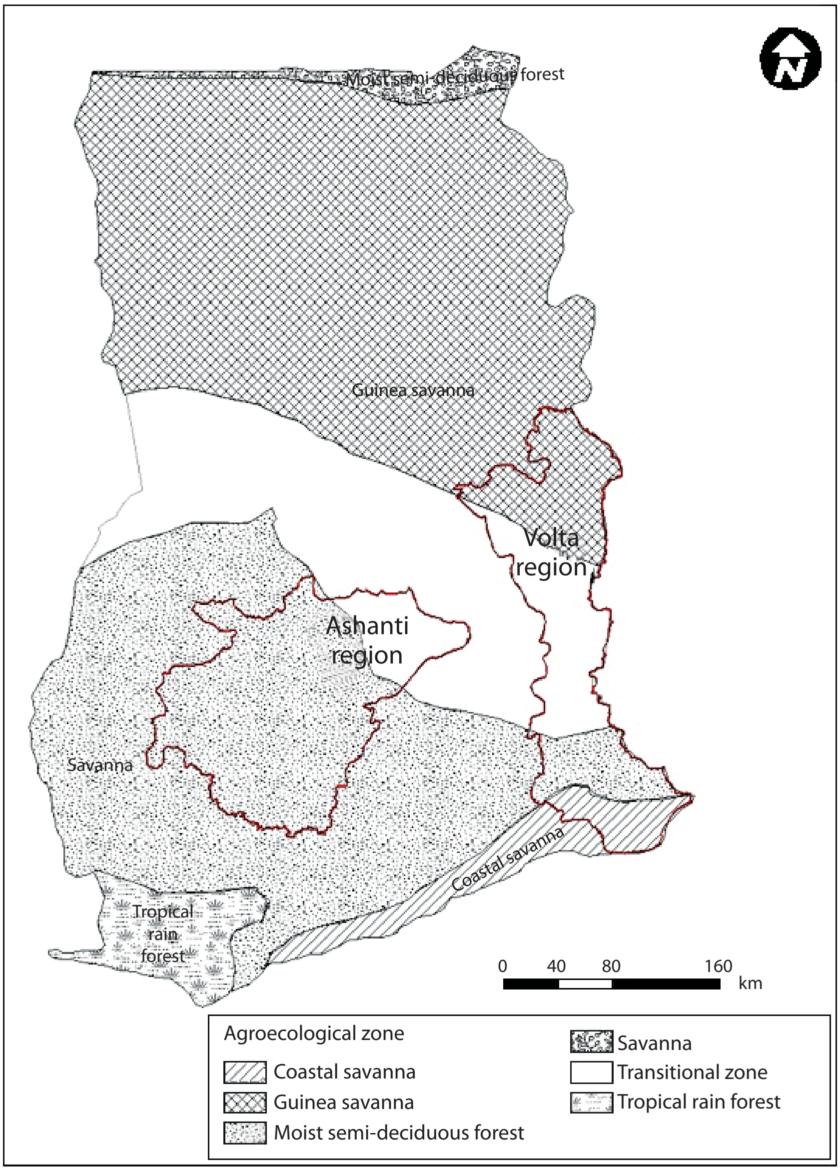
To explore these questions, we conducted this study in the two Ghanaian regions of Ashanti and Volta. These two regions were selected for our study because they are known to have recorded the highest rates of TP sales in Ghana. The Ashanti region recorded approximately 38 percent of total TP sales while the Volta region recorded 15 percent of the total TP sales in Ghana (EW 2004). Figure 1 shows the location of the two regions within Ghana with a description of the agroecology of the two regions.

Description of Study Areas

The Ashanti region lies in the south-central part of Ghana occupying an area of 24,389 square kilometers (km^2). The region falls within the equatorial monsoon belt, which is characterized by two main seasons, wet and dry. The wet season is associated with a double maxima rainfall regime from April to July (mean annual rainfall = 1,270 mm) and September to October (mean annual rainfall = 1,778 mm). The region is well endowed with rivers and lakes including man-made ones. Rain-fed agriculture is predominantly practiced, and is associated with the cultivation of major staples such as maize, cassava, plantain, yam and some vegetables. Informal irrigation with the use of watering cans and buckets is extensively practiced in the dry season for the cultivation of both exotic and indigenous vegetables. In and around the capital city, however, vegetables are cultivated throughout the year, particularly exotic vegetables. These include lettuce, cabbage, carrot, spring onion, garden egg and green pepper.

The Volta region is located in the eastern part of Ghana sharing the eastern border with the Republic of Togo. It is the fourth largest region in Ghana, covering a surface area of about 20,570 km^2 (Ghana Statistical Services 2002). It has a mean annual rainfall of between 140 mm and 165 mm. The southern part of the region is located in the dry equatorial zone, which according to Dickson and Benney (1977) is the driest climatic zone in Ghana. Temperatures are generally high (between 26 ^{o}C and 28 ^{o}C) throughout the year. The region's main river is the Volta; it is also served by several smaller rivers and streams. Farming is the dominant form of land use and the main source of income for most households in this region (Duncan and Brants 2004). This is related to the predominantly rural character of the region and the fact that the region is moderately endowed with natural resources and fertile soils. Although dry-season vegetable cultivation is widely practiced, some districts cultivate vegetables throughout the year. Rain-fed agriculture involves the cultivation of major staples including cassava, maize, rice and yam. Cocoa and coffee are important export crops cultivated in the forest zones. Fishing is another important income-generating activity, especially for communities along the coastline and Lake Volta. Both exotic and indigenous vegetables are irrigated and these include shallots, onions, okra, pepper and tomatoes.

FIGURE 1.
Map of Ghana showing study areas: Ashanti and Volta regions.



Study Design and Data

The study was carried out primarily through a survey of 108 farmers: 52 adopters and 56 non-adopters of TP in August and September 2005. In obtaining the sample for the survey, a multistage sampling technique was used. First, the districts in each of the regions with more adopters of TP were sampled using the sales list provided by the EW. In all, five districts were selected in the Volta region and seven in the Ashanti region. Second, farmers in each selected district were stratified into two, namely adopters of TP and non-adopters. Adopters were identified by using the sales list and through assistance from sales agents. In some cases, farmers assisted in identifying other users. The non-adopters of TP were distributed throughout the selected districts. These were farmers who irrigated using the traditional water-lifting devices such as rope and bucket and/or watering cans. Third, all TP adopters who were available in these districts were interviewed. Those who had stopped the use of the pump were also interviewed. In sampling non-adopters, a simple random sampling technique was used. A questionnaire was used to obtain farm- and household-level information from adopters and non-adopters. The data collected from the survey were supplemented by interviews with TP manufacturers and sales agents to distill information on the level of local capacity for the manufacture and dissemination of the TP. The promotion of TP by EW in Ghana was only for a period of 2 years, between 2002 and 2004. Because the study was conducted in 2005, it was only able to assess the short-term impact of TP adoption in Ghana.

The data were analyzed using descriptive statistics, budgetary analysis, production function analysis and the Heckman's two-step procedure. The t-test statistic and chi-square were used to test for significance in differences in socioeconomic characteristics and indicators of poverty impacts between adopters and non-adopters.

Analytical Framework

Factors That influence Adoption of TP

The decision to adopt an agricultural technology depends on a variety of factors (Nowak and Korsching 1983; Wiersum 1994; Mendola 2005; Calatrava-Leyva et al. 2005), including farm households' asset bundles and socioeconomic characteristics, characteristics of the technology proposed, perception of need and the risk-bearing capacity of the household. An "asset bundle" comprises physical, natural, human, social and financial assets. In this study, we hypothesize that the factors affecting TP adoption are as follows:

Physical/natural assets. The area of land under irrigation is expected to affect the adoption decision. Farmers with less than a hectare of irrigated farm are expected to be willing to adopt the technology since the area is within the pump's capacity to irrigate. The size of irrigated land cultivated depends on the availability and the financial capacity of the farm household for cultivation. It is therefore used as a proxy of the family's wealth status. Reliable access to water throughout the year is also considered a factor in whether or not the TP will be adopted.

Human assets. The quality and quantity of household labor are expected to affect adoption decisions. The quality of household labor is captured by the capacity to work proxied by the age of farm household head, and the capacity to adopt proxied by the level of education of household head. The quantity of household labor is captured by the household size and the ratio of family members who do not earn an income to those who earn (dependency ratio) and the number of household members who can assist in operating the TP (those who are 15 years and above). TP adoption is expected to have a negative relationship with the age of household head and dependency ratio; TP adoption is expected to have a positive relationship with the level of education of household head, household size, and household members above 15 years of age. The gender of the household head is included to examine its impact on adoption decisions, although no negative or positive relationships are hypothesized for this relationship.

Social assets. These are represented by membership in the farmers' cooperative society and frequency of extension visits. Membership in the cooperative society and high frequency of extension visits are expected to increase adoption. These variables are expected to improve the adequacy of the information obtained about the pump, which will have an impact on the adoption decision.

Financial assets. This is proxied by the access of the farm household to formal or informal credit. Access to credit has remained a constraint to adopting improved technologies in developing countries and access to credit is expected to affect the adoption decision positively.

The adoption of TP technology can be analyzed by employing either the logit model or the probit model. To assist in testing for selectivity bias in the outcome equation, however, the Heckman two-step procedure was used to estimate both the adoption model and the poverty impact model (outcome equation). The explanatory variables in the adoption model are age of household head, years of schooling of household head, household size, household members above 15 years, dependency ratio, irrigated land area, membership of association, number of extension visits per year, gender, accessibility to credit, reliability of water and region.

Impact of TP Adoption on Poverty

Several authors have attempted to define the link between irrigation and poverty (Hazell and Haggblade 1993; Datt and Ravallion 1998; Hussain and Hanjra 2003; Lipton et al. 2003; Saleth et al. 2003). The effects of irrigation on rural poverty are transmitted through a long chain of intermediate variables such as irrigated area, cropping intensity, productivity of land and labor resulting in changes in production levels and labor. This study assesses the poverty impact of the TP for irrigation by estimating changes in these variables and its aggregate impact on farm income. A further step is taken to evaluate impacts of these income changes on key social and economic indicators, such as expenditure on education and home improvement and food security.

There are several different ways to quantify these impacts. Two commonly used approaches are (a) "before and after" comparisons and (b) "with and without" comparisons. One of the problems with "before and after" comparisons is that it fails to account for changes in production that would occur without the project and therefore can lead to erroneous estimates of the quantified impacts (Gittinger 1982). Although the "with and without" approach also suffers from similar limitations, it is commonly used in real-world impact assessments. It is suggested that, where data are available, both approaches should be adopted to gain more insights into impact (Hussain and Bhattarai 2005). This study has used the "with and without" comparison.

Impact on production and labor. Changes in production levels are measured by changes in irrigated area, cropping intensity, crop diversification and productivity of land. Those for labor are mainly changes in quantity of labor use and labor productivity. Crop diversification was measured using the Herfindal Index expressed as:

$$\text{Herfindal Index} = \sum_{i=1}^{n} \left(Ai/A \right)^2 \qquad (1)$$

where,

Ai = area cultivated under the i^{th} crop
A = total area cultivated under all crops
n = total number of crops cultivated

Impact on land and labor productivity. To determine land and labor productivity, a production function was fitted to the data for adopters and non-adopters of TP and a comparison made between the two groups. The production function is expressed as:

$$Y_i = f(X_{ij}\,;\beta) + \mu_i \quad i = 1, 2 \ldots, n \qquad (2)$$

where,

Y_i = gross value of production of the i^{th} farm in $

X_{ij} = vector of actual j^{th} inputs used by the i^{th} farm

β = vector of parameters to be estimated

μ_i = error term of the i^{th} farm

i = 1, 2, 3, … n farm

The inputs are:

X_1 = irrigated area in hectares

X_2 = labor in man-days

X_3 = quantity of fertilizer in kg

X_4 = number of irrigations

By specifying the dependent variable, the methodology used by Arega and Rashid (2003) was adopted. The dependent variable was estimated as the gross value of production in view of the mixed cropping pattern of the sample farms. Summing up the output of the farms from the various cultivated crops was difficult due to their differential units of measurement. Thus, the values from all crops cultivated under irrigation were estimated. The data were fitted with the Cobb-Douglas production function.

Impact on farm income from irrigated crop production. The farm income was estimated using a budget analysis. This involves the deduction of all production costs from the total value of output. The total cost of production includes the cost of labor, seeds, fertilizer, herbicides and pesticides, land rent and the depreciation of farm assets. The depreciated value was obtained using the straight-line method.

The budget function can be expressed as:

$$\mathrm{FI_i} = \sum_{k=1}^{m} P_k Y_k - C_k \tag{3}$$

where,

FI_i = income of the i^{th} farm in $

P_k = the farm gate price of the k^{th} crop

Y_k = total output of the k^{th} crop

C_k = total cost of producing the k^{th} crop

k = 1, 2,3 …m crops cultivated

i = 1, 2, 3, … n farms

Impact on poverty status of adopters. In order to further investigate the impact of the TP adoption on the poverty status of adopters, a multivariate analysis was done. To isolate the impact of TP adoption from other intervening factors, the establishment of a counterfactual outcome is required, as is the ability to overcome selection bias. According to Heckman and Smith (1999), the establishment of a counterfactual outcome represents what would have happened in the absence of project intervention. Zaini (2000) asserts that these problems become more complicated when participants self-select into the project. Due to the difficulty of establishing an effective counterfactual situation, a control group was used which comprised non-adopters of TP. To allow for selection bias in the assessment of the poverty impact of TP adoption, the identification variable approach following the Heckman two-step procedure was adopted to analyze the data. Selection bias relates to the unobservable factors which may bias the outcome on poverty due to TP adoption. An appropriate identification variable for this two-step procedure needs to be found for the analysis. This variable has to influence adoption but not poverty. Moreover, even if an appropriate identification variable is found, the results from the procedure can be sensitive to the choice of this variable. Due to this limitation, the results from the procedure need to be checked for “robustness” (Zaman 2000). This report adopted the “number of extension visits per year” as the identification variable that influences adoption but not poverty. The choice is dictated by the fact that an increase in the number of extension visits increases farmers’ knowledge about the TP and helps them make an informed decision as to whether or not to adopt. The impact of extension visits on poverty will depend not only on the number of extension visits per year but also on the quality of extension services rendered. The impact of this variable was tested in the adoption and poverty models to verify its choice as an identification variable.

The Heckman two-step procedure involves, first, the estimation of the adoption process and second, the estimation of the poverty outcome. Following Zaman (2000), the adoption equation (the first step of the Heckman two-step procedure) estimated is:

$$Y_i^* = \sigma_0 + \sum_{i=1}^{n} \delta_n X_i + \mu_i \tag{4}$$

where,

Y_i^* = a latent variable representing the propensity of a farm household i to adopt TP

X_i = the vector of farm households' asset endowments, household characteristics and location variable that influence the adoption decision

σ_0, δ_n = parameters to be estimated

μ_i = error term of the i[th] farm household

i = 1, 2, 3, … n farm households

Prior to the analysis, pair-wise correlation was conducted for the variables in the model and it was found that some of the variables were highly correlated. One of each pair of the highly correlated variables was dropped.

Employing the maximum likelihood estimation procedure, the probability of adoption is obtained from the first step of the Heckman two-step procedure. This involves employing a probit regression to predict the probability of adoption. Using these estimates, a variable known as the Mills ratio is obtained as follows:

$$\lambda_i = \phi(\rho + \delta X_i) \div \varphi(\rho + \delta X_i) \tag{5}$$

where,

λ_i = the Mills ratio term

X_i = the vector of farm households' asset endowments, household characteristics and location variable that influence the adoption decision

ϕ = the density function of a standard normal variable

φ = the cumulative distribution function of a standard normal distribution

ρ, δ = parameters

The second step involves adding the Mills ratio to the poverty equation. The factors that determine poverty are explicit in the literature and they include household and community characteristics. Lack of household ownership and access to assets that can be put to productive use are important determinants of poverty (Ellis and Mdoe 2003; World Bank 2000). The specific factors identified in the literature that determine poverty include demography or human factors (e.g., household size, age and gender, education and health) and social capital (membership in mutual support organizations); physical capital (ownership of livestock and other productive assets); community factors (access to infrastructure and services, population density, urban-rural or regional location; and external factors (civil strife, climate) (Benin and Mugarura 1999).

The household and community characteristics with institutional factors hypothesized to affect poverty are similar to those hypothesized to affect adoption. They are the age of the household head, household size, dependency ratio, number of years of schooling of household head, irrigated area, membership of water user or cooperative association, the geographical location of the study area and the household TP adoption status. The poverty status of the household is represented by its per capita income. The household per capita income was obtained by dividing the total household income by the number of adult equivalent in the household. The household income includes income from irrigated farming, rain-fed farming, livestock production, off-farm activities, nonfarm activities and remittances.

The poverty equation is given as:

$$P_i = \beta_0 + \beta_1 W_i + \beta_2 Y_i + \beta_3 \lambda_i + \xi_i \tag{6}$$

where,

P_i = per capita income of farm household i in $

W_i = a vector of farm household's asset endowments, household characteristics and location variable

Y_i = a dummy variable which is 1 for adopters and 0 for non-adopters

λ_i = the Mills ratio term

ξ_i = error term of farm household i

$\beta_0, \beta_1, \beta_2, \beta_3$ = parameters to be estimated

i = 1, 2, 3, … n farm households

Results and Discussion

Socioeconomic Characteristics of TP Adopters and Non-Adopters

The summary statistics of the socioeconomic characteristics of adopters and non-adopters of TP are given in table 2. It is evident that irrigated farming is male-dominated with the percentage of males generally high in the study areas. There is a small but significant difference in the years of schooling of household heads among adopters and non-adopters, with the former being more educated. So while the age and gender of adopters and non-adopters do not differ significantly, adopters were, on average, better educated.

The household demographics show that the mean household size of adopters is significantly lower than that of non-adopters. There is also a trend towards higher numbers of adult males, and lower numbers of adult females, in adopter households, but these differences were not significant. The dependency ratio of non-adopters is higher and significantly different at 10 percent from that of adopters. This implies that the ratio of non-working members to working members is higher in non-adopter households. Therefore, labor availability is lower in these households than in adopter households. About half of all farmers in the study area belong to farmers' associations, and had similar limited access to credit, irrespective of whether they were adopter or non-adopter households. The mean difference in number of extension visits per year is 2.24 and it is significant at 1 percent.

Land tenure patterns are similar for both adopters and non-adopters. Inheritance and rent are the most common tenure arrangement. About 28.85 percent and 35.71 percent obtained their land by inheritance among adopters and non-adopters, respectively. Rents in cash or on crop share basis represent tenure arrangements for 65.38 percent of adopters and 57.14 percent of non-adopters. Those who purchased their land represented 5.77 percent of adopters and 3.56 percent of non-adopters. Others obtained land on mortgage.

TABLE 2.
Characteristics of adopters and non-adopters of TP.

Characteristics	Adopters	Non-adopters	% Difference	Chi-square value/t-test
Age of household head	41.38	43.32	4.68	1.041
Gender of household head-male (%)	94.23	98.21	3.98	+1.200
Years of schooling of household head	10.63	9.30	12.51	1.801*
Household size	5.97	6.78	13.56	1.693*
Adult male above 15 years	2.14	1.98	7.48	+1.042
Adult female above 15 years	2.12	2.21	4.25	+0.358
Dependency ratio	0.67	0.77	14.93	1.810*
Irrigated area	0.66	0.58	1.12	1.440
Member of association (%)	48.07	55.35	7.28	+0.572
Number of extension visits per year	4.31	2.07	51.97	2.456***
Access to credit (%)	5.76	1.78	3.98	+1.091

Notes: ***significant at 1%; *significant at 10%; +chi-square values.

Awareness and Rationale for Adoption and Stopping the Use of the TP

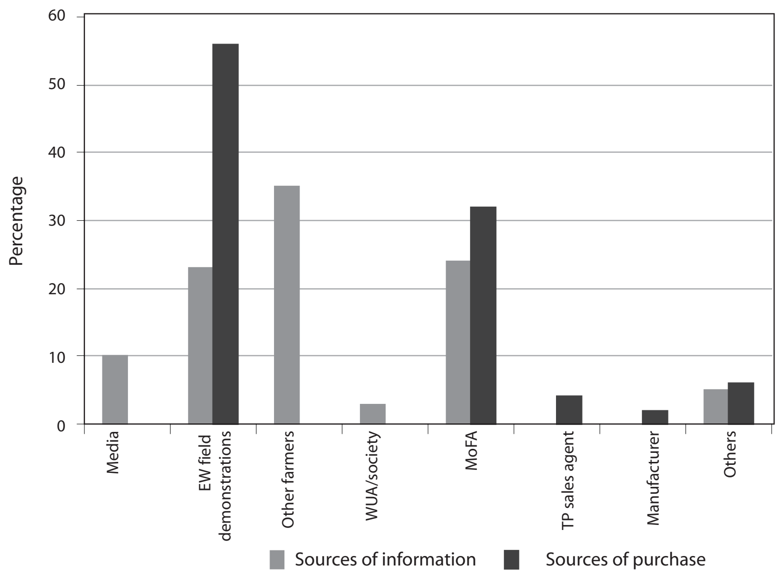
Level of awareness. The sources of information and sources of purchase of TPs by survey respondents varied (figure 2). The major sources of information on TP to farmers were information dissemination by other farmers (35%), Ministry of Food and Agriculture (MoFA) extension agents (24%) and EW field demonstrations (22%). EW field demonstrations accounted for more than half (56%) of the TP sales outlet; MoFA sales agents accounted for 32 percent while the manufacturers (local artisans) sold only 2 percent of the pumps directly to farmers. These results confirm the active roles of EW in facilitating the diffusion of TP among farmers in the study regions. These findings suggest that TP manufacturers have little influence in the sale of their products.

Rationale for TP adoption and non-adoption. For all the adopters, 59 percent claimed reduction in aggregate labor use for irrigation as the reason for TP adoption, while 49 percent mentioned time savings in irrigation as the reason for TP adoption (figure 3). Other important reasons that accounted for TP adoption are increased irrigated area (31%), non-requirement of fuel (29%) and the affordability of the TP (8%).[5] The results thus indicate that the most important reasons for TP adoption are reduction in labor use for irrigation and time-saving irrigation.

The most-cited reasons for not adopting TPs are that they were considered (a) unaffordable by many (58%) and (b) a problem as they required at least two workers to irrigate at one time (31%). Other reasons that made TP less attractive were a lack of suitability for cultivating large irrigated area (19%), lack of awareness (14%) and, to a small extent, lack of a reliable water source (4%).

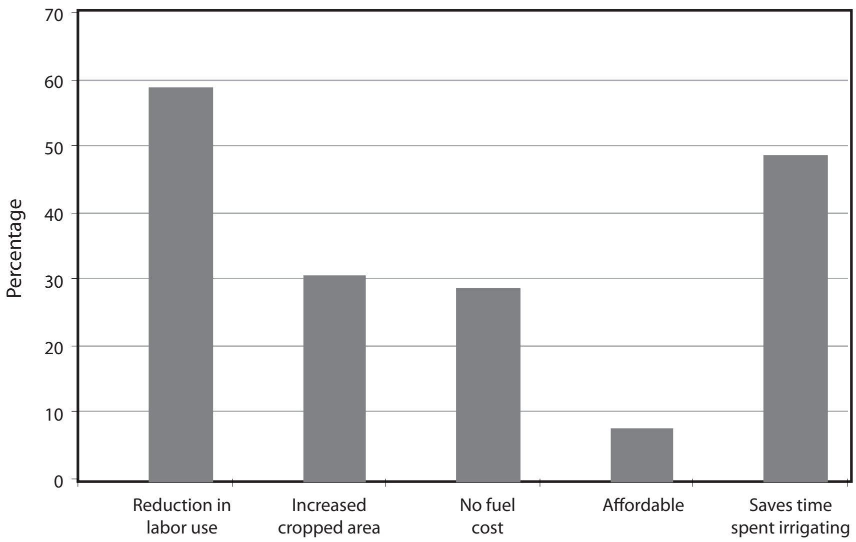
Factors that influence stopping the use of the TP. Our survey revealed that about 21 percent of all adopters had subsequently stopped using the TP. As shown in table 3, the reasons given by the respondents for stopping the use of the TP included: bought motorized pump, TP had broken down, unsuitable for large extents of land and unreliable water source. In the Volta region, five of the adopters were able to purchase motorized pumps. While some farmers have been able to purchase motorized pumps in the Volta, none did

FIGURE 2.
Sources of information and purchase of TPs.



[5]Values add up to more than 100 percent due to multiple responses.

FIGURE 3.
Reasons given by adopters for adoption of the TP.



so in Ashanti. This may be because farmers in the Volta region irrigate all year-round while farmers in the Ashanti region irrigate mainly only during the dry season. In Ashanti, the breakdown of the TP is given as the most important reason for stopping the use of the TP. The frequent breakdown of TPs may be a reflection of lack of after-sales service following the exit of EW. This fact was corroborated in the interviews conducted with local manufacturers who claimed not to have after-sales services. They are willing, however, to assist in repairs for a fee. The inability to cultivate large areas is cited by 15 percent of farmers who have stopped using the TP.

TABLE 3.
Reasons for stopping the use of the TP.

Reasons	Percent of adopters		
	Volta	Ashanti	Pooled
Bought motorized pump	25	-	10
TP has broken down	30	15	21
Cannot be used in large areas	30	6	15
Unreliable source of water	-	6	4

Note: Multiple responses were given.

Factors that Influence TP Adoption

Explanatory variables and summary statistics used in the adoption model are presented in table 4. Diagnostic statistics (table 5) showed that the model had a good fit to these variables with log likelihood scores that are significant at 1 percent and with the signs of the variables agreeing with *a priori* expectations, except the variable for age of household head. Three of the variables were statistically significant at 5 percent. These were the dependency ratio, number of extension visits per year and the regional dummy. Dependency ratio has a negative relationship with the probability of adoption and is significant at 1 percent. Increase in the number of nonworking household members as compared to those working infers lower labor availability for productive economic activities. This apparently discouraged TP adoption, which requires labor for pedaling. Also, increase in the number of dependants in the family may reduce the household income available for investments, thus discouraging adoption. The number of extension visits per year is positive and significant at 5 percent showing that the higher the frequency of visits the higher the probability of TP adoption. The regional dummy is significant at 5 percent, and with a negative sign, implies that the Ashanti region has a higher probability of adoption than

TABLE 4.
Summary statistics of the explanatory variables for the adoption model.

Variables		Mean	Std. dev.
Age of household head in years	Age of the household member responsible for final decisions on farm operations and investments	42.30	1.80
Year of schooling	Number of years of formal education of household head	9.94	3.89
Household* size	Total number of members of the household	6.30	0.19
Household members above 15 years	Total number of household members above 15 years representing the adult workers in the household	4.23	2.26
Dependency ratio	Ratio of non-income-earning members of the household to income-earning members of the household	0.72	0.01
Irrigated area (ha)	Area of land cultivated under irrigation before adoption	0.59	0.41
Membership of association	Dummy variable for membership of water user association, farmer cooperative society; 1 for members, 0 for nonmembers		
Number of extension visits	Number of visits from MoFA and EW per year	3.10	1.83
Gender	Dummy variable for gender; 1 for male, 0 for female		
Accessibility to credit	Dummy variable for accessibility of credit from formal and/or informal sources; 1 for accessibility and 0 otherwise		
Reliability of water	Dummy variable for availability and accessibility of water throughout the year; 1 for reliability of water, 0 otherwise		
Region	Dummy variable for region; 1 for Volta, 0 for Ashanti.		

Notes: *A household is taken as the number of members who eat from the same pot over a 12-month period; Std. dev. = standard deviation.

TABLE 5.
Factors that influence the adoption of the TP using the Heckman two-step procedure.

Variable	Coefficient	Standard error	Z	P-value
Constant	-0.261	0.724	0.361	0.717
Age	0.009	0.016	0.567	0.571
Years of schooling	0.050	0.041	1.211	0.226
Household size	-0.025	0.055	-0.464	0.642
Dependency ratio	-0.808***	0.280	-2.880	0.004
Irrigated area	0.248	0.363	0.683	0.495
Membership of association	-0.109	0.296	-0.370	0.711
Number of extension visits per year	0.067**	0.336	1.999	0.045
Reliability of water	0.358	0.309	1.159	0.274
Region	-0.766**	0.316	-2.421	0.015
Log-likelihood	- 60.572			
Chi-square	28.428			
Probability of chi-square	0.0081			
N	108			

Notes: *** Significant at 1%; ** Significant at 5%.

the Volta region. In the Ashanti region, there is easy access to big commercial markets particularly for exotic vegetables, which serves as an incentive for farmers.

This study shows that the age of household head, years of schooling, irrigated area and the reliability of water supply have positive relationships with the probability of adoption, but are not significant. Similarly, household size and membership of associations have negative relationships with the probability of adoption but are not significant. Due to data constraints, the size of irrigated farm is used as a proxy for wealth status in this study. The variable is positive but not significant. This means that although increases in the size of irrigated area may increase the probability of adoption, we cannot make conclusions on whether or not TP technology self-selects the poor in the study area. A similar study in Asia by Shah et al. (2000) stated that the TP adopters come second to diesel pump owners in terms of landownership; they were not the poorest landowners and certainly not the landless. They stressed that this has led to the "TP trickle down" hypothesis in which the pioneers tend to be the less poor; but over time, as the technology blends into the social fabric, the poor tend to adopt it. On the whole, this result revealed that availability of labor and the increase in the number of extension visits per year will increase the probability of adoption. In addition, there was a higher probability of TP adoption in the Ashanti region than in the Volta region.

TABLE 6.
Cropping intensity and diversification indices of adopters and non-adopters of TP.

	Cropping intensity	Diversification indices
Volta		
Adopters	1.48	0.30
Non-adopters	1.42	0.28
P-value	0.225	0.845
Ashanti		
Adopters	1.87	0.34
Non-adopters	1.57	0.30
P-value	0.085*	0.636
Pooled		
Adopters	1.68	0.32
Non-adopters	1.52	0.29
P-value	0.166	0.710

Note: *Significant at 10%.

Impacts of TP Adoption

Cropping intensity and diversification indices. The cropping intensities of adopters and non-adopters are shown in table 6. The P-values were obtained from a t-test of mean differences between adopters and non-adopters in the same region and for all farmers. In all cases, cropping intensity is greater than 1. The cropping intensities for TP adopters are higher than for non-adopters in both regions but significant at 10 percent in the Ashanti region only. This implies that the adoption of the TP increases cropping intensities, although the extent differs between locations and among farmers. The diversification index of farms does not differ significantly between TP adopters and non-adopters.

Land and labor dynamics. Irrigated areas for both adopters and non-adopters were less than one hectare each but the adoption of a TP resulted in an increase in land area cropped for adopters. The mean irrigated farm size of adopters and non-adopters was 0.66 hectare and 0.58 hectare, respectively, a difference of 12 percent but not significant (t-value=1.440, p=0.153). Individual farmers did increase irrigated area, with about 14 percent, doubling their irrigated area in the Volta region while 17 percent cultivated more than 0.8 hectare in the Ashanti region. In all, about 26 percent achieved an increase in size of irrigated area after TP adoption.

Family and hired labor is intensively used and the form of labor use depends on the farm operation. Often, labor is hired for land preparation, weeding and harvesting. Family labor is used for nursery preparation, transplanting, spraying and irrigation. Inadequate family labor, however, places constraints on farmers who therefore occasionally hire labor for irrigation. The average total labor used per hectare is 173.4

labor-days for adopters and 218.7 labor-days for non-adopters, resulting in a difference of 45.3 labor-days, which is significantly different at 1 percent (t value=2.734, p=0.007). The study revealed that the average time spent irrigating by adopters is 3 hours per irrigation while non-adopters spent 4.75 hours per acre of farm (0.4 ha). This result corroborates the finding of Kamara et al. (2004), which demonstrated in a "before and after" analysis of labor use per farm in the Ashanti region that 68 percent of farms recorded a decrease in irrigation time after adoption. They noted a decrease of 34 percent in the total number of hours used on irrigation after the adoption of a TP. Farmers' agree that increasing the irrigated area has resulted in increases in labor for most farm operations but contend that the decrease in labor for irrigating has resulted in a decrease in total labor use per farm. Our result is, however, inconsistent with the impact of TP on labor use in Niger where the average number of persons working on a farm increased by an average of 2.3 persons after adoption of TP was recorded (ANPIP 2005). This was recorded over a period of 6 years during which time significant increases in irrigated area occurred.

Land and labor productivity. Table 7 presents the results of the estimated Cobb-Douglas production function.

The estimated equations represent a good fit of the data with a high coefficient of determination of 73 percent and 65 percent for the estimated parameters for TP adopters and non-adopters, respectively. The estimated coefficients represent the elasticities of production with respect to each input.

The analysis reveals that for TP adopters, the coefficients of irrigated area, labor, fertilizer and the number of irrigations are positive and are significant at varying levels. This indicates that increases in these inputs will lead to an increase in the gross value of production. The sizes of the coefficients reveal that area cultivated and fertilizer used have the highest impact on the gross value of production followed by number of irrigations and labor. The gross value of production for non-adopters also increases with irrigated area and labor. These variables are significant at 1 percent and 5 percent, respectively. The coefficients on fertilizer and number of irrigations are positive though not statistically significant. Table 8 shows the marginal value productivities with respect to these inputs.

The adoption of TP has resulted in higher productivities in irrigated area, labor and fertilizer than among non-adopters. The size of the marginal value products shows that a unit increase in irrigated area and fertilizer will increase gross value of output by $392.21 and $5.22, respectively, for TP adopters, while a unit increase in irrigated area and fertilizer will increase output by $231.59 and $0.26, respectively, for non-adopters of TP. This is an indication of higher productivities for TP adopters

TABLE 7.
Estimated production function coefficients.

	Adopters		Non-adopters	
Variable	Coefficient	Standard error	Coefficient	Standard error
Intercept	4.926***	0.390	6.178***	0.231
Irrigated area	0.244***	0.062	0.216***	0.025
Labor	0.003*	0.002	0.008**	0.003
Quantity of fertilizer	0.285***	0.049	0.019	0.030
Number of irrigations	0.201**	0.076	0.054	0.038
R^2	0.731		0.650	
F value	29.170***		25.552***	
N	52		56	

*Notes:****Significant at 1%; **Significant at 5%; * Significant at 10%.

TABLE 8.
Estimated marginal value productivities (in $).

	Adopters	Non-adopters
Irrigated area (ha)	392.21	231.59
Labor (labor-days)	0.027	0.018
Fertilizer (kg)	5.22	0.26
Number of irrigations	1.59	4.52

than for non-adopters. The gain in gross value of output for adopters, as a result of per unit increase in labor, increases by a factor of 1.5 when compared with those of non-adopters. The results also revealed that there is a possibility of increasing gross value of output by $1.59 for each additional irrigation for TP adopters and $4.52 for non-adopters of TP. This implies that non-adopters have a higher potential to increase their gross value of output substantially by increasing the number of irrigations. Overall, the results demonstrate that TP adoption has a positive and higher impact on the productivity of land, labor and fertilizer while non-adopters have a positive and higher productivity on the number of irrigations. In view of the fact that TP adopters and non-adopters operate in the same input and output markets, it is evident that the increase in marginal value productivity of inputs is, in part, due to increases in output. Our results show improved land and labor productivity as a result of TP adoption.

Income from irrigated crop production. The profitability of production is estimated on a per farm and per hectare basis using equation 3, and the results are given in table 9. The total revenue per hectare for TP adopters is higher than for TP non-adopters. The difference is statistically significant at 5 percent (t-value= 2.394, p=0.019). Similarly, the net income for TP adopters is also higher than for non-adopters, and the difference is statistically different at 1 percent (t-value =2.611, p=0.012). The same pattern is observed in the two regions studied. In addition, higher total revenue and net income were obtained in the Ashanti region than in the Volta region. On an average irrigated area of 0.66 hectare for adopters, a net income of $952.43 was earned while it was $608.89 on 0.58 hectare for non-adopters. This represents a difference of $343.54 which is significant at 10 percent (t-value =1.835, p=0.070). Kamara et al. (2004) reported that gross revenue increased from $454 before adoption to $882 after adoption, and net revenue increased from $181.05 to $443.26. In all cases, adoption of TP does increase net farm income. This is consistent with the previously reported findings of EWW (2003). Similar results were reported in other parts of Africa, notably Kenya, Zambia and Malawi (Kay and Brabben 2000; Mangisoni 2006). For example, in Kenya, income ranged between $80 for non-adopters and $690 for adopters.

TABLE 9.
Income from irrigated farms (in $).

	Per farm			Per hectare		
	Total revenue	Total cost	Net income	Total revenue	Total cost	Net income
Adopters						
Volta	847	265	582	1,883	588	1,295
Ashanti	1,865	531	1,334	2,361	672	1,689
All*	1,361	409	952	2,062	619	1,443
Non-adopters						
Volta	758	290	468	1,263	484	779
Ashanti	816	201	615	1,511	371	1,140
All	856	247	609	1,476	426	1,050

Note: * All respondents from the Volta and Ashanti regions.

Impact on poverty status. A multivariate analysis was undertaken to assess the impact of TP adoption on poverty using the Heckman two-step procedure. Essentially, the explanatory variables include the same household and community characteristics, as well as institutional factors, as in the adoption model. The second step of the Heckman two-step procedure estimates the determinants of poverty and tests for selectivity bias by incorporating the Lambda into a linear regression. The Lambda is the inverse Mills ratio saved from the probit equation describing adoption. The dependent variable is the log of the household per capita income. The selection of the identification variable was tested by estimating the determinants of poverty. The model was estimated using the number of extension visits per year as the identification variable. Table 10 presents the coefficients in the poverty model from both the second step of the Heckman two-step and the OLS (Ordinary Least Squares) estimation procedures. The Lambda coefficient is negative and is not significantly different from zero which indicates the absence of selectivity bias in the sample. This means that the error terms of the adoption and poverty models are not correlated. The robustness of the identification variable was tested using the "identification on functional form" method. This involves including the identification variable in the model. Again, the Lambda coefficient was not significant. The identification variable was also not significant, which implies that it does not influence the per capita income of farm households in the study area. Therefore, it is possible to judge the variable appropriate for an identification variable. Since the results from the estimation can, however, be sensitive to the choice of the identification variable and in the two models the Lambda is not significant, the model can be estimated using an OLS.

The result from the OLS estimation is used to explain the model. Three of the variables are positive and significant at different levels. These are years of schooling, irrigated area and TP adoption. The regional dummy is also significant but has a negative sign. The years of schooling of household head is positive and significant at 1 percent. The per capita income will increase by 7 percent for each additional year of schooling. This implies that the education of household head had an impact on poverty. This is not surprising. Literacy can enhance the capacity to adapt to change, understand new practices and technologies, and improve a household's productivity and income. The size of irrigated area is positive and significant at 1 percent. A unit increase in irrigated area leads to about 74.9

TABLE 10.
Determinants of poverty.

	Heckman second step with number of extensions as identification variable	Heckman second step and identifying on functional form	OLS estimation
Variable	Coefficient	Coefficient	Coefficient
Age	-0.001(p=0.87)	-0.001(p=0.89)	-0.001(p=0.83)
Years of schooling	0.073***(p=0.00)	0.073***(p=0.00)	0.072***(p=0.00)
Household size	-0.005(p=0.78)	-0.005(p=0.77)	-0.005(p=0.78)
Dependency ratio	0.016(p=0.85)	0.016(p=0.86)	0.027(p=0.76)
Irrigated area	0.739***(p=0.00)	0.742***(p=0.00)	0.749***(p=0.00)
Membership of association	-0.031(p=0.74)	-0.035(p=0.71)	-0.036(p=0.71)
Number of extensions		0.002(p=0.87)	0.001(p=0.91)
Reliability of water	-0.001(p=0.98)	-0.002(p=0.98)	0.007(p=0.93)
Adoption of TP	0.247**(p=0.04)	0.243**(p=0.03)	0.281***(p=0.00)
Region	-0.205*(p=0.06)	-0.205*(p=0.06)	-0.194*(p=0.07)
Lambda	-0.012(p=0.45)	-0.011(p=0.44)	

Notes: *** Significant at 1%; ** Significant at 5%; * Significant at 10%.

percent increase in per capita income. An increase in irrigated area will increase farm output and incomes and thereby improve household per capita income. The adoption of the TP is positive and significant at 1 percent. The result shows that the TP adoption increases per capita income by 28.1 percent relative to that of a non-adopter. The regional dummy is significant at 10 percent and this implies that the per capita income of farm households in the Volta region was 19.4 percent lower than the per capita income of those in the Ashanti region. On the whole, the increase in irrigated area has the highest impact on poverty followed by TP adoption, and lastly the number of years of schooling. The higher per capita income of farm households in Ashanti as compared to Volta is partly due to its better access to markets. This shows that the adoption of a TP reduces poverty. This result is consistent with findings in a similar study in Malawi (Mangisoni 2006).

Food security. Since the crops (mainly vegetables) are grown for sale, adopters explain that they consume less than 5 percent of their harvest. They stated, however, that the increase in incomes has enhanced their ability to improve the status of their food security. They all indicated that they do not have to skip meals as a means of coping with food insecurity. The results of this study are consistent with some earlier findings. For instance, Kamara et al. (2004) assessed the dynamics of household food security for Ghana's rainy and dry seasons, which are normally characterized by different levels of food availability. The results show that 68 percent of the adopters got their daily meals in both the rainy and dry seasons, and none recalled problems with food availability in either season. They observed that the overall food security situation has improved. This agrees with the findings in Malawi where 91 percent of the adopters – including those who were food-insecure prior to TP adoption – noted that they are now food-secure, i.e., they have enough food to last until the next harvest every year (Mangisoni 2006).

Social and economic impacts. The impact of TP adoption on social and economic indicators as perceived by the adopters is shown in table 11. A great impact was observed on improvement in human capital as incomes were used to pay for children's schooling. This was common in both regions. In addition, cash is available to pay for health services which are expected to have a positive impact on farmers' productivity and household income. For example, the table shows that some economic impact was achieved by TP adopters. About 28 percent of the adopters were

TABLE 11.
Impact on social and economic indicators.

Impact indicator	Percent of adopters		
	Volta	Ashanti	Pooled
Improved ability to pay fees	75	71	73
Sent children for higher education	25	21	23
Enhanced ability to pay for health services	40	50	46
Joined more social associations	5	6	5
Felt more respected in the community	10	12	11
Started another business	15	37	28
Improved house quality/built a house	10	6	7
Acquired television or radio	10	12	11
Bought livestock	-	3	3
Acquired farm assets	10	18	15

Note: Values add up to more than 100 percent due to multiple responses.

able to start new businesses while 15 percent were able to acquire farm assets. The new businesses often involved starting with petty trading while farm assets included simple farm tools and sprayers. About 11 percent claim to feel more respected in the community while an equal number were able to acquire household assets. Impact on acquisition of landed properties and livestock is low, apparently due to the high capital requirement of such investments.

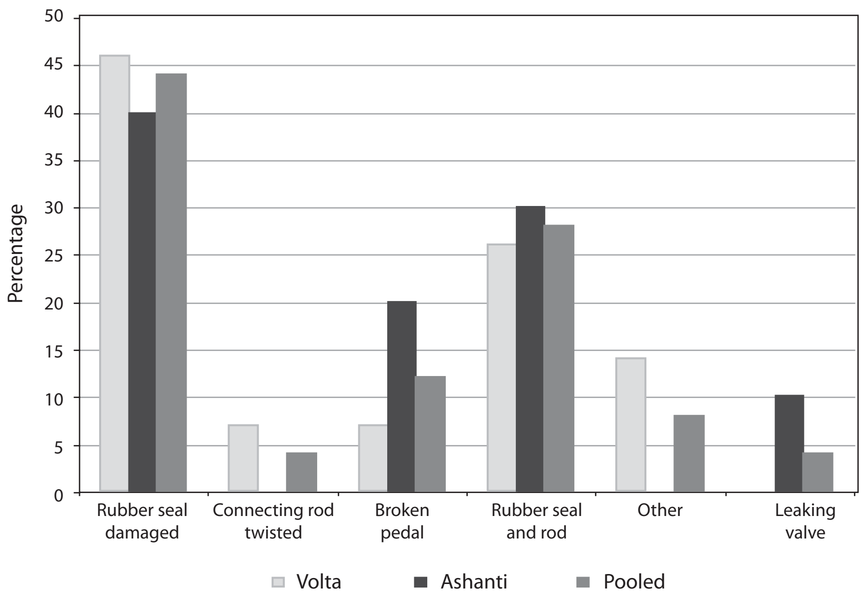
Gender Status of Adopters

Almost all the adopters were men, with less than 2 percent being women. Men are responsible for the procurement, operation and maintenance of the pumps. They pedal while women assist with water distribution. These women are normally family members and do not participate in the lifting of water. All the farmers claimed that they did not hire female labor for lifting water because they considered it an arduous task for women. Women are active during harvesting and marketing, thus creating productive employment for them. Kamara et al. (2004) observed that the difficulty for women to operate the pumps has cultural dimensions. Pedaling the pump with an up-and-down leg motion while being elevated above the ground makes women feel uncomfortable and undignified, particularly in the presence of men. This contrasts with the situation in Kenya where pumps are purchased by men but are mostly managed by women who hire young men to operate them (Brabben and Kay 2000). In cases where farm families have been able to start other businesses, however, some women have benefited by getting funds to start petty trading. This implies that women benefit indirectly from TP adoption. There is, however, a need to make the pump gender-neutral so that women can also adopt the technology and benefit from it directly.

Local Capacity for TP Repair, Manufacture, Promotion and Sales

Repairs among adopters. Fifty percent of the TP adopters in the Volta region and 46 percent of TP adopters in the Ashanti region have changed at least one component of the pump within the 2-year period of adoption. As shown in figure 4, the component often changed is the rubber seal.

FIGURE 4.
Components often repaired in the TP.



Other components that sometimes require repairs are the twisted connecting rod, pedal and leaking valves. In some other cases, a mix of these components has been repaired. The study reveals that repairs were mainly carried out by the farmers themselves followed by EW and lastly by the local manufacturers (see table 12). This indicates that farmers, if they are well trained and have access to markets for the spare parts, can repair the pumps themselves.

Manufacture, promotion and sales. Twenty-one manufacturers were trained by EW in Ghana, but only nine remained in production as of 2005. Altogether five manufacturers and two sales agents were interviewed. Two of the manufacturers were from the Volta region and the others from the Ashanti region while the sales agents were mainly from the Volta region. The local artisans were generally below 45 years of age and had a basic school education. They were all trained by EW for 2 weeks and were given simple tools and materials to start off. The materials required for the manufacture of the pumps are available locally in Ashanti, but manufacturers in the Volta have to travel to the capital city of Accra to obtain them. While the project lasted, EW supplied the rubber seal components and occasionally checked to ensure that the quality of the pumps was in line with the set standard for its manufacture. The unit cost of a manufactured TP varies from $55.6 to $88.9 in Volta and $55.6 to $66.7 in Ashanti. The sales price also varies from $83.3 to $94.4 in Volta and $88.9 in Ashanti, a mark up of about 23 percent and 45 percent, respectively, using average values. Pumps are sold directly to farmers or marketed by sales agents in the Volta region, while they are marketed by EW, MoFA and sales agents in the Ashanti region. By the end of 2004, 711 pumps had been sold over a period of 2 years but annual sales dropped that same year. The bulk of the pumps were sold in 2003, the first year after the introduction of the pump. The exit of EW at the end of its project life in 2004 resulted in a dismal sales performance in 2005. This underscores the limitations of the project approach to

TABLE 12.
Channel for repairs of the TP.

Channel	Percent of adopters		
	Volta	Ashanti	Pooled
EW	33	28	30
Local manufacturers	-	21	21
Farmer himself/herself	50	42	45
Sales agent	7	-	7

development and suggests that a program of a longer duration might be more effective. The manufacturers express their interest in continuing the manufacture of the pumps because it improved their incomes. The level of patronage is, however, very low and they expressed the need to increase awareness about the pumps. The use of the media, demonstrations on farmers' days and the active involvement of agricultural extension workers are suggested to improve awareness and motivate farmers to adopt the TP.

Only two of the manufacturers have each trained three people to manufacture pumps; other manufacturers are usually assisted by one of their trainees or do it by themselves. The need to ensure that standards are adhered to for the manufacture of good-quality pumps is often cited as the reason for limiting the number of workers trained. In addition, the current level of demand does not require many workers.

Manufacturers do not give special sales incentives to farmers but they are allowed to make deposits and pumps are delivered to them on the payment of the full sum. There is no after-sales service rendered and repairs are left to the farmers and, in some cases, to the sales agents. Farmers who are willing to pay and transport their pumps to manufacturers' workshop are, however, assisted. The sales agents offer farmers incentives in the form of two installment payments to be made usually within a period of 3 months. They identified problems of lack of adequate installation personnel, particularly when the farm is located in remote areas, and lack of repair training for farmers after the exit of EW. They suggested the training of at least one manufacturer in every district to ease access to the pumps and installation.

Conclusions

In Ghana, the TP is a technology that can replace the existing rope and bucket irrigation which is very labor-intensive. Thus a major attractive feature of the TP is that it reduces time and labor requirements for irrigation. Other factors which made the TP attractive to farmers included opportunities to increase the size of irrigated area and cost reductions for irrigation due to nonuse of fossil fuel. It was not possible to ascertain whether or not TP technology self-selects the poor as is hypothesized. Even with this low-cost technology, the purchase cost was seen as the most significant barrier to adoption. The technology is clearly not gender-neutral in Ghana, and there are significant social barriers to the adoption by women.

This study confirms the positive impacts of TP technology including reducing poverty, by enabling increases in cropping intensities, area of irrigated cropland and farmers' incomes. More importantly perhaps, TP use in the study areas increased land and labor productivity, which is essential for poverty alleviation. The net income was increased by approximately $393 per hectare. Other important impacts were the improvements in human capital (realized through extra spending on education and health care) and food security.

Despite the obviously positive impacts realized by adopting farmers there appears to be limitations to the effectiveness of marketing efforts in the region, and/or to TP suitability. Clearly, a sustained market had not yet been created when EW activities ended, since TP sales dropped soon afterward. It was also observed that the strategy to manufacture TP at different locations by EW in Ghana posed quality-control difficulties and a threat to the sustainability of its dissemination. It is recommended that a variety of improvements in design, dissemination and capacity building might improve the impact of TP technology in West Africa. While development organizations have strategies that, for good reasons, reject subsidies, and work almost exclusively through private enterprise as a dissemination vehicle, the approach may have limitations with respect to achieving sustainability and poverty-alleviation goals. It is recommended that a program designed with local institutions for disseminating and marketing the TP may be more effective and sustainable than projects of short duration. Increased collaboration with local institutions, such as extension agents, could be made to increase sustainability and improve access for farmers. Design improvements should be undertaken to ease pedaling so as to encourage the uptake of TPs by women and enhance their chances of benefiting directly from the pumps. An introduction of an after-sales service and training farmers on minor repairs will also improve the continuous use and sustainability of the pumps.

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