The Livelihoods Impacts of Irrigation in Western Africa: The Ghana Experience

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Abstract: Although agriculture remains the mainstay of the African economy, it is currently going through stress because of a multitude of factors including climate change. Thus, many countries in their efforts to transform their agricultural sectors are employing climate-smart initiatives including the provision of water harvesting technologies for irrigated crop production during the dry season. This paper examines the role of irrigation in the drive towards a transformation of smallholder agriculture in Africa. Focus group discussions, key informant interviews and individual questionnaires were employed for the data collection. The data were analyzed using the regression adjustment (RA) technique. The results indicate that irrigation has significant and positive impacts on farm incomes, employment, consumption, food security and non-farm businesses, all of which are necessary conditions for a successful transformation of smallholder agriculture in Africa. The impacts of irrigation on health and environmental sustainability are mixed—the positive being the ability of irrigators to pay for improved healthcare for their families and the negatives include the outbreak of waterborne diseases associated with irrigation water. Construction of irrigation facilities causes destruction to the environment but improves provisioning ecosystem services. It is generally concluded that access to irrigation is associated with higher farm incomes, employment, consumption, food security and engagement in non-farm business activities. The key policy implication of these findings is that African governments must formulate strategic policies that will accelerate investments in the provision of irrigation facilities to better promote the agenda to transform smallholder agriculture in the continent.

Keywords: Africa; Ghana; irrigation; livelihoods; smallholder

1. Introduction

Agriculture remains the main source of livelihoods to a large proportion of people resident in rural Africa and Ghana for that matter. In the specific case of Ghana, it is estimated that nine out of ten people in rural areas derive their livelihoods from agriculture and agriculture-related activities [1]. Rural livelihoods are, however, currently going through stress due to the adverse effects of climate change. Crop yields continue to dwindle, as rainfall patterns are now unpredictable. There are instances of double tragedy of droughts and floods occurring within the same seasons. The experience in recent times has been either too high or too low rainfalls and each of these episodes negatively affects agricultural production and rural livelihoods for that matter [2]. The situation is particularly dire in northern Ghana, which experiences uni-modal rainfall patterns. The key to getting out of this phenomenon is to institute mechanisms that ensure a stable supply of water for production purposes and one of such mechanisms is the provision of irrigation facilities [3].

The provision of irrigation facilities in strategic locations in rural areas, especially in northern Ghana, is expected to help promote livelihoods in those areas [4–7]. This is because
it has been established in the empirical literature that access to irrigation has positive impacts on agricultural production and the reduction of poverty levels of farmers [8]. Access to irrigation provides farmers with a reliable water source at critical times in the crop’s life cycle, removing the dependence and inherent uncertainty of rain-fed and lake-based agricultural systems in arid and semi-arid areas. Irrigation minimizes unforeseen production shocks particularly relating to bad weather conditions. In India, irrigated crop production had a 2.5 times lower standard deviation of crop output per year than rain-fed crop production [8]. Small-scale irrigation schemes in particular are said to have impacted rural lives in Africa. From a case study of a small-scale irrigation scheme in Zimbabwe for instance, Dube [9] showed that farmers who engage in small-scale irrigation had improved incomes and better food security and quality life.

To take advantage of the positive impacts of irrigation, small-, medium- and large-scale irrigation schemes have been provided across Ghana and elsewhere in Africa to enhance agricultural production and encourage all year production, which will ultimately lead to improvements in livelihoods through increased food availability and income levels. There are even advocacies to re-appraise the dynamics of irrigation development in Africa to include farmer-led initiatives to ensure the effectiveness of irrigation schemes [10]. The involvement of farmers ensures that suitable technologies from local knowledge are applied to meet specific livelihood needs. That notwithstanding, the ownership structure as well as the maintenance culture of irrigation facilities is crucial in their sustainability [11,12].

Despite the concerted efforts spanning decades to facilitate rural livelihoods development using irrigation as a strategic tool, there is still a high incidence of poverty across the continent and Ghana in particular. This raises fundamental questions among researchers, policy makers, policy implementers and development practitioners about the role of irrigation in transforming smallholder agriculture in Ghana and Africa generally. This paper therefore examines the role of irrigation in transforming smallholder agriculture in Africa using evidence from Ghana by assessing the different irrigation impact pathways.

From the foregoing, it is clear that access to irrigation has positive and significant links with the livelihoods of farmers and farm households. This paper adds to the evidence of the central role irrigation should play in the agricultural transformation agenda being pursued in Africa for poverty reduction and socio-economic development. The rest of the paper includes the materials and methods, results, discussion and concluding sections.

2. Research Methodology

2.1. Study Description

The paper employs mixed methods and the main reason for using mixed methods is to provide the opportunity for triangulation and cross-validation. This makes it possible for the issues under consideration to be looked at from different viewpoints by offsetting the weaknesses inherent in each individual method while drawing from their strengths to ensure rigor in the research findings. The qualitative methods used provided the opportunity for an in-depth understanding of the different irrigation pathways that better promote the livelihoods development of beneficiary rural dwellers. These methods involved the use of participatory qualitative research tools such as focus group discussions, key informant interviews, in-depth interviews and so on for the data collection. The quantitative methods are used to quantify, where possible, the contribution of the different irrigation pathways to the livelihoods of beneficiary rural households. The main quantitative research tool used in the paper is a household survey conducted through questionnaire administration.

A total of 32 focus group discussions were conducted with irrigators and non-irrigators across gender and generation in 8 communities across four districts in Ghana with irrigation facilities. In addition, 60 people deemed to have in-depth knowledge in irrigation and rural livelihoods issues were interviewed as key informants. These included influential farmers, policy makers, policy implementers, change workers, traditional rulers and local government authorities. The survey covered a total of 864 households in four districts with
irrigation facilities across scales. The households were selected across the different wealth classes (i.e., poor and rich) according to local standards.

The selection of districts, communities, households and individuals to participate in the study was through multistage sampling processes. Data analyses included thematic, content and discourse analyses as well as econometric modeling for the estimation of the contribution of the different identified irrigation impact pathways across the study areas.

2.2. Analytical Framework

The analysis in this paper is based on field research, mainly community-level focus group discussions, key informant interviews and a household survey in selected irrigation sites in northern Ghana. The study was conducted in the second quarter of 2015 and the survey was a non-random experiment. This means that identification problems exist, leading to selection bias arising from two main sources. The first source of selection bias is the non-random assignment of irrigation projects to communities using implicit targeting rules, which has implications for access to irrigation water. Thus, the factors considered in allocating irrigation projects might correlate with the outcome variables of interest. For instance, irrigation projects might be allocated either to highly productive areas to ensure success or to less productive areas to improve farm productivity, which could be an outcome as well as a selection variable. In either case, the estimates of irrigation effects or impacts derived from outcome indicators will contain upward or downward biases, respectively. The second source of bias is the non-mandatory participation in irrigation as a livelihood activity. Access to irrigation might be correlated with household characteristics such as education, which may influence the likelihood of technology adoption, access to water and whether households live in rural or urban areas. Education may also influence outcomes such as income levels. To deal with the non-randomized participation in irrigation in the selected sites and adoption decisions by households within these sites, different estimation strategies are possible. These include difference-in-differences, propensity score matching and matched difference-in-differences [13–17].

Ideally, the effects of an intervention could be determined by regressing a set of explanatory variables (regressors) with outcome variables of interest (regressands). However, this approach will not yield the true effects because of biases arising from unobserved characteristics that may also have influences on the outcomes of interest. For instance, those households that participated in irrigated agriculture could have self-selected themselves based on the fact that they may be more entrepreneurial or have farmlands closer to water sources than their non-participating counterparts and these could potentially affect output levels and household incomes, assets or investments for that matter. The problem is compounded by the fact that these are mostly unobservable to researchers. It is therefore important to isolate these unobservable factors so as to be able to estimate the true effects of participation in irrigated agricultural production.

To account for self-selection and other factors resulting in “selection bias”, it is important to adopt the appropriate estimation strategies. As such, treatment effect methods (regression adjustment, nearest-neighbor matching and propensity score matching) are the available methods that could be used to estimate the true effects of participation in irrigated agriculture on the outcomes of interest. These methods use the observed demographic information about individuals and households, as well as the known fact of whether or not the household is participating in irrigated agriculture or not to develop a probability of treatment for each household, based solely on observed covariates. The individual and household characteristics used are specified in the selection model. By dealing with selection bias, we are able to produce estimates of treatment effects with greatly reduced bias. Treatment effect according to Hamilton [18] refers to the impact of receiving a certain treatment, in this case participation in irrigated agriculture upon a particular outcome variable, specifically household incomes, household consumption and employment. The treatment effect ensures that the effect on the outcome variable is solely attributed to the se-
lection variable (participation in irrigated agriculture) and not any other factors. According to Hamilton [18], the treatment effects are computed mathematically as follows:

\[ t_i = \text{treatment category} \begin{cases} 1 & \text{for participation in irrigation} \\ 0 & \text{otherwise} \end{cases} \] (1)

\[ ATE \equiv E\{y_{1i} - y_{0i}|x_i\} \] (2)

where \( ATE = \text{Average treatment effect} \); \( x_i = \text{characteristics of } i\text{th farmer} \)

\[ ATET = E\{y_{1i} - y_{0i}|x_i, t_i = 1\} \] (3)

According to Pinzon [19], Bittmann [20] and Lipton et al. [21], the potential-outcome means (POM) estimated using regression adjustment (RA) specify that the observed outcome (\( y \)) is \( y_0 \) when the adoption category (\( t \)) = 0 and that \( y \) is \( y_1 \) when \( t = 1 \). This is expressed mathematically as

\[ y = (1 - t)y_0 + ty_1 \] (4)

The functional forms for \( y_1 \) and \( y_0 \) are

\[ y_0 = x'\beta_0 + \epsilon_0 \] (5)

\[ y_1 = x'\beta_1 + \epsilon_1 \] (6)

The impacts of participation in irrigated agriculture were thus estimated using RA. The RA estimators use means of predicted outcomes for each treatment level to estimate each potential-outcome mean. The RA estimates the potential-outcome mean (POM), which is the means of the potential outcomes for a specific treatment level. For example, the mean household incomes if a farmer was participating in irrigated agriculture and the mean household incomes if no farmer participated in irrigated agriculture.

2.3. Empirical Model Specification

Participation in irrigation, \( Y \) by individual \( i \), is a function of individual-, household- and irrigation-specific characteristics (Table 1). Each of these characteristics either positively or negatively influences the decision of individuals and farm households to participate in irrigation as a livelihood activity. Mathematically, this is expressed as follows:

\[ Y(Y_1; Y_2; Y_3) = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + a_4X_4 + a_5X_5 + a_6X_6 + a_7X_7 + a_8X_8 + a_9X_9 + a_{10}X_{10} + a_{11}X_{11} + a_{12}X_{12} + a_{13}X_{13} + a_{14}X_{14} + a_{15}X_{15} + a_{16}X_{16} + \epsilon \]

Table 1. Variables, mode of measurements and hypotheses.

| Variable | Variable Description | Mode of Measurement | Hypothesis |
|----------|-----------------------|---------------------|------------|
| \( X_1 \) | Generation of respondent | Elderly = 1; Otherwise = 0 | +/- |
| \( X_2 \) | Gender of respondent | Male = 1; Female = 0 | + |
| \( X_3 \) | Age of respondent | Years | + |
| \( X_4 \) | Respondent’s age squared | Years | - |
| \( X_5 \) | Respondent’s marital status | Married = 1; Otherwise = 0 | + |
| \( X_6 \) | Formal schooling by respondent | Years | + |
| \( X_7 \) | Origin of respondent | Native = 1; Otherwise = 0 | +/- |
| \( X_8 \) | Gender of household head | Male = 1; Female = 0 | + |
| \( X_9 \) | Household size of respondent | Number of people | - |
| \( X_{10} \) | Alternative livelihood activities | Yes = 1; Otherwise = 0 | + |
| \( X_{11} \) | Food shortage previous year | Yes = 1; Otherwise = 0 | - |
| \( X_{12} \) | Irrigation type | Formal = 1; Otherwise = 0 | + |
| \( X_{13} \) | Irrigation Scale 1 | Medium = 1; Otherwise = 0 | + |
| Variable   | Variable Description       | Mode of Measurement                  | Hypothesis |
|------------|----------------------------|--------------------------------------|------------|
| $X_{14}$   | Irrigation Scale 2         | Large = 1; Otherwise = 0             | +          |
| $X_{15}$   | Water conveyance method 1  | Pump = 1; Otherwise = 0              | +          |
| $X_{16}$   | Water conveyance method 2  | Gravity = 1; Otherwise = 0           | +          |

**Treatment Variable**

| Category                              | Participation in irrigation | Yes = 1; Otherwise = 0 | +/−        |

| Outcome Dependent Variables            |                           |                        |            |
|----------------------------------------|---------------------------|------------------------|------------|
| $Y_1$ Total agriculture income         | Ghana Cedis               |                        |            |
| $Y_2$ Total household consumption      | Ghana Cedis               |                        |            |
| $Y_3$ Employment duration              | Weeks of work             |                        |            |

Source: authors’ conceptualization, 2020.

3. Results

The results indicate that irrigation has the potential to take the center stage for the agricultural transformation agenda in Africa through the different impacts on livelihoods. These include direct and indirect impacts as well as on-farm and off-farm impacts. Each of these impacts critical in the transformation of smallholder agriculture in Africa and the promotion of rural livelihoods development is discussed in the following subsections.

3.1. Socio-Demographics of the Research Participants

Demographically, the study participants were both irrigators and non-irrigators from different backgrounds (Table 2). Generally, there was a lower number of elderly people (19%) engaged in irrigation compared to those in only rain-fed agriculture (38%). Similarly, there were more men (48%) as non-irrigators than irrigators (35%) with the majority (72%) of non-irrigators being married compared to the irrigators (46%). The majority (81%) of non-irrigators were natives compared to the irrigators (52%) and this is understandable given that people move out of their locations where there might not be irrigation facilities to places where such facilities exist to be able to produce during the off-season. Again, an overwhelming majority (91%) of the non-irrigator households were found to be male-headed compared to that of irrigators (54%). The results (Table 2) show that almost twice (85%) the proportion of non-irrigators had alternative livelihood activities compared to irrigators (45%). The majority (52%) of the non-irrigators reported experiencing food shortages compared to only a few (9%) irrigators who experienced food shortages (Table 2) and this is understandable because irrigators have a longer supply of food from their farms compared to non-irrigators.

Averagely, the results show that irrigators earn more from their farms (GHS2,844) than non-irrigators (Table 3). Similarly, the non-irrigators spend less on household consumption (GHS1,175) compared to irrigators (GHS1,896) and this might explain why a lower number of irrigators reported food shortages. Further, while on average non-irrigators are found to be in effective employment for only 15 weeks (approximately 3 months and 3 weeks) in a year, irrigators are effectively employed for 21 weeks (approximately 5 months and 1 week) in a year (Table 3). Non-irrigators earn less (GHS1,227) from their non-farm or alternative livelihood activities than irrigators (GHS2,019).
Table 2. Descriptive of the socio-demographics (nominal variables).

| Variable                  | Non-Irrigators | Irrigators |
|---------------------------|-----------------|------------|
|                           | Frequency       | Percent    | Frequency | Percent |
| Generation of respondent  | 167             | 38         | 81        | 19      |
| Gender of respondent      | 208             | 48         | 147       | 35      |
| Marital status of respondent | 314          | 72         | 195       | 46      |
| Origin of respondent      | 350             | 81         | 221       | 52      |
| Gender of household head  | 393             | 91         | 230       | 54      |
| Alternative livelihood activities | 369        | 85         | 191       | 45      |
| Experienced food shortage  | 222             | 52         | 40        | 10      |
| Medium irrigation scheme  | 0               | 0          | 104       | 24      |
| Large irrigation scheme   | 0               | 0          | 21        | 5       |
| Water conveyance by pump  | 0               | 0          | 21        | 5       |
| Water conveyance by gravity | 0            | 0          | 102       | 24      |
| Irrigation type (formal)  | 0               | 0          | 125       | 29      |

Source: authors’ computations, 2020.

Table 3. Descriptive of the socio-demographics (continuous variables).

| Statistic                  | Non-Irrigators | Irrigators |
|----------------------------|-----------------|------------|
|                            | Min  | Max  | Mean | Std Dev. | Min  | Max  | Mean | Std Dev. |
| Farm income (GHS)          | 100  | 7000 | 1727 | 1849     | 300  | 10,000 | 2844 | 1980      |
| Consumption (GHS)          | 65   | 5200 | 1175 | 1068     | 195  | 6500  | 1896 | 1285      |
| Employment (weeks)         | 0    | 43   | 15   | 12       | 0    | 53    | 21   | 11        |
| Non-farm income (GHS)      | 71   | 4970 | 1227 | 1312     | 213  | 7100  | 2019 | 1406      |
| Age (years)                | 18   | 87   | 42   | 15       | 18   | 80    | 41   | 12        |
| Household size (people)    | 1    | 75   | 5    | 6        | 0    | 145   | 5    | 8         |
| Education (years)          | 0    | 6    | 2    | 2        | 1    | 6     | 2    | 1         |

Source: authors’ computations, 2020.

In terms of age, household sizes and education, there are no marked differences in the results (Table 3). Most of the irrigators were into small-scale irrigation followed by medium-scale irrigation, with only a few being into large-scale irrigation (Table 3). It was also found that most of the irrigators relied on manual watering of their crops and this was followed by those who use gravity flow to convey water to the crop fields for watering (24%), with only a few (5%) using water pumps. Further, the majority (71%) of irrigators are on informal irrigation schemes, with only 29% being on formal schemes (Table 3). The crops grown under irrigation include tomatoes, onions, pepper, rice, maize and leafy vegetables such as lettuce and cabbage. The rain-fed crops include millet, rice, soybeans, sorghum, maize, yam and groundnut.

3.2. Impacts of Access to Irrigation on Farm Incomes

The study results revealed that the immediate and direct impact of irrigation on livelihoods and transformation of smallholder agriculture is through output levels. Irrigation increases total output in three ways. The first is that irrigation augments water supply and helps to reduce crop losses through erratic rainfall. Additionally, irrigation permits multiple and continuous cropping in a year and hence total farm output increases per parcel of land in a year. Finally, in areas where land is available but water supply is minimal or seasonal, irrigation allows for intensive crop cultivation. In other words, irrigation
brings about increases in output levels because of the use of complimentary inputs such as fertilizers, high-yielding crop varieties and modernized technology as experienced in the green revolution. The increases in outputs lead to increases in income, ceteris paribus. This assertion is consistent with the views of [22], in that irrigation could boost annual output and raise income levels when there are no significant changes in prices. It must, however, be noted that incomes will decrease if increases in outputs are accompanied by more than proportional declines in prices. Participants of the focus group discussions and key informant interviews indicated that irrigation has greatly impacted their livelihoods through improved output levels, and this is helping them transition from smallholder agriculture to medium- and large-scale farm production.

The results indicate that if there were no irrigation facilities in the studied communities, the income levels of farmers would have been significantly lower. In other words, if no farmers in the community were involved in irrigated agriculture, the average farm income would have been about GHS 1881.80 (USD 493.91) and this was found to be significant at 1%. With the presence of irrigation facilities across the communities, the average farm income is about GHS 2717.62 (USD 713.29) and this was found to be statistically significant at 1% (Table 4). The implication of these findings is that irrigation brings about an increase in income levels and this is consistent with the empirical literature.

| Farmer Category | Coefficient | Robust Std. Err. | Z      | P > |z| | 95% Conf. Interval |
|-----------------|-------------|------------------|--------|-----|---|------------------|
| Non-irrigators  | 1881.799    | 116.423          | 16.16  | 0.000 | 1653.614 | 2109.985          |
| Irrigators      | 2717.622    | 123.898          | 21.93  | 0.000 | 2474.786 | 2960.459          |

Source: authors’ computations, 2020.

3.3. Impacts of Access to Irrigation on Employment

Irrigation reduces poverty through employment by creating farm labor for the farmer, wage labor for others and labor for the construction and maintenance of irrigation facilities. According to [23], irrigation projects firstly require labor for the construction and maintenance of canals, wells and pumps, which is important to the poor, especially the landless rural poor households with excess labor or seasonal excess labor. Results from the focus group discussions and key informant interviews revealed that irrigation creates employment by stimulating demand for farm labor in two ways: in the main cropping season and the minor cropping season. This increases the number of workers required and the length of the employment period. The depth of rural poverty reduces by increased employment opportunities, leading to agricultural transformation. The poverty impact will be positive if vulnerable groups, normally the poor and landless, especially women, are rewarded. Additionally, the focus group discussion participants and key informants indicated that irrigation creates all-year-round employment opportunities for irrigators and non-irrigators, thereby reducing seasonal migration to urban areas. This reduces the number of job seekers moving to urban centers, which could relieve the downward pressure on urban wages and the upward pressure on prices of housing and other urban infrastructure.

The results indicate that if there were no irrigation facilities in the studied communities, the employment levels would have been significantly lower. The results revealed that if no farmers in the selected communities were involved in irrigated agriculture, the average duration of effective employment would be about 13 weeks (3 months) and this was found to be statistically significant at 1% (Table 5). However, with the presence of irrigation facilities in the communities, the average duration of effective employment is about 20 weeks (5 months) and this was found to be statistically significant at 1% (Table 5). The implication of these findings is that irrigation brings about an increase in employment levels as farmers work for a longer period and this is consistent with the empirical literature cited above.
3.4. Impacts of Access to Irrigation on Consumption and Food Security

Household consumption, including food and non-food expenditures, is a critical measure of standard of living [1]. The focus group discussions’ participants and key informants noted that irrigation brings about increases in production, as indicated earlier, that lead to an increase in the quantity of food available for household consumption. They noted that because of irrigation, they now have an extended period of supply of fresh farm produce for household consumption and sale for income to buy other consumable goods not produced by farm households. The extended supply of fresh food according to them leads to a reduction in food prices and improvement in food security. In fact, the benefits of an extended fresh food supply go beyond irrigators and irrigated communities for that matter. This is consistent with the view of Lipton [24], in that the positive impact of irrigation on net purchasers of food will be high because of cheaper food, likely to result in poverty reduction. The implication of this is that low-income and possibly poor smallholder farmers in non-irrigating communities who are likely to be net buyers of food stand to benefit from irrigation due to falling food prices occasioned by the extended supply made possible by irrigation.

Waged agricultural laborers, in addition to increased employment, will benefit from lower prices because they will have more purchasing power. This is because they will find their wages buy more food as a result of falling prices. The effect of irrigation on prices and therefore on poverty may be particularly strong in remote areas or countries with high transport costs where, prior to irrigation projects, a food deficit had to be compensated by purchase from other regions. It will also affect areas with a comparative advantage in food production, which can respond more strongly to the availability of irrigated land (having a surplus of land or labor) and areas with high surplus output levels, which can be traded in wider markets. Irrigation is therefore likely to reduce poverty among net food purchasers in irrigated and non-irrigated areas as well as the urban poor. In addition, there might be positive effects on net food producers and waged laborers if increases in output and employment outweigh the effects of price falls. This is increasingly likely with the liberalization of food trade, with falls in the growth rate of irrigated areas and with better transport and falling transport/production cost ratios [24–27].

The RA results revealed that irrigation has a significant and positive impact on farm household consumption and food security. The results showed that the average household consumption expenditure would have been about GHS 1236.83 (USD 324.63) if there were no irrigation facilities in the communities (Table 5). On the other hand, with the presence of irrigation facilities in the selected communities, the average household consumption expenditure was found to be about GHS 1955.21 (USD 513.18) and this is statistically significant at 1% (Table 6). The implication of this is that irrigation generally boosts the consumption and food security situation of farm households and this is critical for the transformation of smallholder agriculture in Ghana and Africa generally.

### Table 5. RA results of POM on employment (n = 855).

| Farmer Category | Coefficient | Robust Std. Err. | Z   | P > |z|  | 95% Conf. Interval |
|-----------------|-------------|------------------|-----|-----|---|------------------|
| Non-irrigators  | 12.542      | 0.7269           | 17.25 | 0.000 |   | 11.1170 - 13.9663 |
| Irrigators      | 20.415      | 0.9899           | 20.62 | 0.000 |   | 18.4753 - 22.3555 |

Source: authors’ computations, 2020.

### Table 6. RA results of POM on consumption expenditures (n = 855).

| Farmer Category | Coefficient | Robust Std. Err. | Z   | P > |z|  | 95% Conf. Interval |
|-----------------|-------------|------------------|-----|-----|---|------------------|
| Non-irrigators  | 1236.833    | 85.3881          | 14.48 | 0.000 |   | 1069.48 - 1404.19 |
| Irrigators      | 1955.207    | 113.9315         | 17.16 | 0.000 |   | 1731.91 - 2178.51 |

Source: authors’ computations, 2020.
3.5. Impacts of Access to Irrigation on Non-Farm Activities

Most of the impacts of irrigation on non-farm activities are indirect. Results from the focus group discussions and key informant interviews indicate that irrigation promotes non-farm income-generating activities. For instance, the focus group discussion participants and key informants noted that when there are increases in output and incomes as a result of involvement in irrigation activities, with declines in food prices, enriched farmers and workers are able to increase their expenditure on non-food products. This leads to demand for non-food goods and services leading to the establishment of businesses that provide these goods and services. The end result is increased employment opportunities in non-farm income-generating activities such as transportation, petty trading, construction, food preparation and so on. One of the key informants indicated that irrigators are able use the income generated from irrigation activities to invest in non-farm income-generating activities. For example, some smallholder irrigators the selected communities use proceed from their irrigated vegetable farms, particularly onions, to start corner-shop businesses in their communities. Others are able to use their proceeds to build cement block rooms for their family members and this means that there is demand for related products and services such as cement, iron rods, block layers, masons, steel benders, carpenters and laborers, among others. The demand for these non-farm products, services and professionals brings about improvement in the local economy. Some key informants and focus group discussion participants also noted some irrigators use the proceeds from their irrigation activities to purchase motorbikes, motor tricycles and even taxis, thereby creating jobs for mechanics and spare parts dealers in the communities. Besides, young people also start with irrigation and use the proceeds to finance their skills training in dressmaking, carpentry, masonry and hairdressing, among others, helping them to diversify out of agriculture into non-farm livelihood activities.

Specifically, the RA results revealed that irrigation has a significant and positive impact on the non-farm economy of selected communities. The results showed that the average non-farm income of farmers in the selected communities would have been about GHS 1336.10 (USD 350.68) if there were no irrigation facilities in the communities (Table 7). However, with the presence of irrigation facilities in the selected communities, the average non-farm income was found to be about GHS 1929.51 (USD 506.43) and this is statistically significant at 1% (Table 7). The implication of this is that irrigation generally boosts livelihood diversification as farmers are able to cross-invest proceeds from irrigation into non-farm livelihood activities and vice versa. This is very important for the transformation of smallholder agriculture in Ghana and elsewhere in Africa.

| Farmer Category | Coefficient | Robust Std. Err. | Z       | P > |z| | 95% Conf. Interval |
|-----------------|-------------|-----------------|---------|-----|---|-------------------|
| Non-irrigators  | 1336.103    | 82.7614         | 16.14   | 0.000 |   | 1173.84 - 1498.31 |
| Irrigators      | 1929.512    | 86.3922         | 22.33   | 0.000 |   | 1760.19 - 2098.84 |

Source: authors’ computations, 2020.

3.6. Impacts of Access to Irrigation on Health

Results from the focus group discussions and key informant interviews as well as the review of the empirical literature revealed that in a wider socio-economic context, irrigation affects livelihoods in many different ways including the displacement of a large number of people and loss of livelihoods where irrigation projects involve the construction of large dams with associated environmental effects. Access to irrigation may have very high positive impacts on nutritional outcomes, through increased stable food supplies and, sometimes, cleaner water, which brings about improvements in the health status of people in irrigating communities. In addition, increased income levels will allow rural producers, assuming transport costs are not prohibitive, to purchase a wider variety of foods, thereby increasing dietary diversity and ensuring balanced diets. On the flip side,
irrigation, particularly involving canals, reservoirs and tanks, has a negative effect on health as it encourages water-related diseases due to inadequate drainage and renders the microenvironment hospitable to diseases carrying vectors such as mosquitoes and snails that spread malaria and schistosomiasis. Irrigation sites characterized by contaminated water are also responsible for causing serious diseases, from diarrhea (one of the main proximate causes of child mortality) to cholera. It is likely that the poor are more vulnerable to such water-related diseases. The good news, as indicated by the key informants and focus group discussion participants, however, is that increased purchasing capacity of farmers following irrigation projects will make it possible for them to be able to afford to pay for the medical treatment they need to combat water-related diseases.

3.7. Socio-Cultural Impacts of Access to Irrigation

Participants of the focus group discussions and key informants indicated that irrigation affects the socio-cultural aspects of farmers in irrigating communities. According to them, institutional policies of irrigation affect the existing socio-cultural structures and relations in irrigating communities. Equity concerns in terms of distribution of productive resources such as land, farm inputs and water supply, as well as inclusive decision making promoted by irrigation schemes, benefit the poor and vulnerable, especially women and resource-poor farmers. However, irrigation structures that conflict with existing structures are likely not to achieve their poverty impacts.

3.8. Environmental Impacts of Access to Irrigation

Focus group discussion participants and key informants noted that irrigation has positive and negative impacts on the environment. The construction of large dams and canal systems is associated with environmental problems such as the loss of the natural habitat and biodiversity. Generally, irrigation projects have also further detrimental impacts on the environment beyond the construction phase. Water loss through unproductive evaporation, seepage and percolation, possibly inducing problems of waterlogging and salinization, is potentially a negative consequence of irrigation. The positive environmental impacts of irrigation include improvements in the microclimate of irrigated landscapes and delivery of ecosystem services. For instance, the presence of irrigation water performs temperature-regulating functions in irrigable areas, among others.

3.9. Discussion

The results of this study are largely consistent with the empirical evidence that investments in irrigation positively contribute to improvements in livelihood outcomes such as income, health, nutrition, food security and employment [24–26]. The effects of irrigation on livelihoods are particularly high in areas where agriculture is the main source of livelihood. The finding that irrigation positively contributes to farm incomes of irrigators is consistent with the results of Dittoh et al. [24], who evaluated the comparative impact of micro-irrigation technologies at two locations and found that the micro-irrigation adopted in both areas was generally profitable with a significant effect on crop yields. The authors estimated the technical and economic efficiencies in the cultivation of banana, cotton and groundnut under irrigation and the results indicate that the production of these crops using irrigation is technically and economically justifiable. They also assessed the poverty impact of micro-irrigation by comparing the poverty status of irrigators with non-irrigators and concluded that irrigators generally have a higher income status than non-irrigators. It was also observed in the study that irrigation has a significant effect on cropping patterns and intensity as well as the type of crop cultivated. The authors noted, for instance, that irrigators produced higher-value and more water-intensive crops and a higher cropping intensity than the non-irrigators. The results are also consistent with those of Tendeku et al. [6], who observed that participation in irrigation has the power to improve the incomes of women, thereby increasing the nutritional intake of their household members, as women involved in the marketing of their own farm produce spent the majority of their revenue
on household food items. Irrigation also helps improve the decision-making power of female irrigators. The authors also reported that food and nutrition security has improved significantly among irrigators with the availability of fresh vegetables from homesteads.

The results in this paper are not consistent with other studies [22,23] that report that the ability of irrigation as an intervention to promote livelihoods is not as high as expected. Although the majority of farmers who are into irrigation fall under middle-income brackets, most of them are not satisfied with the effect of irrigation on their economic status and general livelihood. The authors noted, for instance, that instead of irrigation promoting the food security situation of irrigators, it rather worsened it. This is because farmers are not able to store their perishable products, hence they are compelled to sell them early normally at low prices, making food scarce at other times of the year. The study concluded that, as modest as it is, the power of irrigation to reduce poverty and improve livelihoods was not as expected due to an array of challenges such as lack of support services and marketing difficulties. This reemphasizes the fact that the poverty impacts of irrigation are dependent on a number of factors which include, but are not limited to, predictable and stable input/output markets, favorable policies, effective institutions and a reliable support environment for farmers. This assertion is consistent with Hussain [26], who in a two-country study reported that production technology, cropping patterns and crop diversification, as well as equity in land distribution, are important in determining the power of irrigation to promote livelihoods. Consistent with the findings in this study, the authors concluded that, in comparing outcomes from irrigated and rain-fed settings in Sri Lanka, the incidence of chronic poverty is lowest in irrigated rather than rain-fed settings, where there is an estimated one-fourth of rain-fed farm households living below the poverty line throughout the year. In Pakistan however, poverty impacts of irrigation were marginal with the incidence of chronic poverty being higher for non-irrigating farm households than irrigating farm households. Following the same argument, irrigating households were identified to have enough food available through the year as compared to rain-fed households in Sri Lanka, with higher household income and expenditure. In the case of Pakistan, improvement in irrigation infrastructure increased cropping intensity and productivity and crop incomes by 5–25% and 12–22%, respectively. The authors further explained that the difference in poverty impacts between the two countries was as result of equity disparities in landholdings.

Our results are further corroborated by Hussain [27], who in a study of six countries that constitute 51 percent of the global net irrigated area reports that household income and consumption levels were 50 percent higher in irrigated areas than rain-fed areas. Again, poverty levels were much lower (20–30%) in irrigated settings than those of rain-fed areas, with chronic poverty more pronounced among rain-fed households. In a study on groundwater irrigation in 35 communities conducted in Ghana by Dittoh et al. [24], various levels of impacts on poverty, food security, employment and income, among others, in the study areas were examined. By employing the Foster–Greer–Thorbecke (FGT) indices with consumption expenditure as a proxy to measure poverty and inequality indices, their result suggested that although poverty levels are generally higher (57%) in the study area than the national average, poverty indices are lower (0.46–0.58) in irrigating households as compared to rain-fed households (0.62). Although disparities exist in income levels and poverty gaps between the two groups, they were found not to be significant. Further econometric analysis from their propensity estimates again revealed that irrigating farmers had either lower poverty or fewer food shortages as compared to rain-fed farmers. However, findings about dietary diversity were mixed and this was said to be due to the mono-cropping pattern of farmers in the study area. Our finding on employment creation by irrigation is consistent with this study [24] that revealed that irrigation has created additional labor demands estimated at 359,511 man-days during the dry season, with an estimated USD 11.1 million or USD 54 per capita income injection for the 35 villages studied.
4. Conclusions

The paper examined the role of irrigation in the drive towards a transformation of smallholder agriculture in Africa. The results indicate that irrigation has significant and positive impacts on farm incomes, employment, consumption, food security and non-farm businesses, all of which are necessary conditions for a successful transformation of smallholder agriculture in the study area, and this could generally be applied to the situation in Africa and elsewhere in the developing world. The impacts of irrigation on health and environmental sustainability are mixed—the positive being the ability of irrigators to pay for improved healthcare for their families and the negatives include the outbreak of waterborne diseases associated with irrigation water. Construction of irrigation facilities causes destruction to the environment but improves provisioning ecosystem services. It is generally concluded that access to irrigation is associated with higher farm incomes, employment, consumption, food security and engagement in non-farm business activities. The general conclusion of the study is that irrigation investments lead to poverty reduction through substantial increases in farm income as a result of increased cropping intensity and area of cultivation, better crop yields and enhanced output quality that is associated with higher output unit prices, among others. The key policy implication of these findings is that the government of Ghana and that of other African countries must formulate strategic policies that will accelerate investments in the provision of irrigation facilities to better promote the agenda to transform smallholder agriculture in the continent.

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References
1. Ghana Statistical Service. Ghana Living Standards Survey Round Six (GLSS6), Accra—Ghana; Ghana Statistical Service: 2014. Available online: https://www2.statsghana.gov.gh/nada/index.php/catalog/72/study-description (accessed on 21 October 2020).
2. Akudugu, M.A.; Dittoh, S.; Mahama, E.S. The Implications of Climate Change on Food Security and Rural Livelihoods: Experiences from Northern Ghana. J. Environ. Earth Sci. 2012, 2, 21–29.
3. Ndirangu, W.; Luwesi, C.N.; Beyene, A.; Akudugu, M.A. Africa’s water sector development and financing outlook. In Innovative Water Finance in Africa: A Guide for Water Managers—Vol. 1: Financial Innovations Context; Beyene, A., Luwesi, C.N., Eds.; Chapter 2; Nordiska Afrikainstitutet: Uppsala, Sweden, 2018; pp. 40–57. ISBN 9789171068156.
4. Agula, C.; Mabe, F.N.; Akudugu, M.A.; Dittoh, S.; Ayambila, S.N.; Bawah, A. Enhancing healthy ecosystems in northern Ghana through eco-friendly farm-based practices: Insights from irrigation scheme-types. BMC Ecol. 2019, 19, 38. [CrossRef] [PubMed]
5. Agula, C.; Akudugu, M.A.; Dittoh, S.; Mabe, F.N. Promoting sustainable agriculture in Africa through ecosystem-based farm management practices: Evidence from Ghana. Agric. Food Secur. 2018, 7, 5. [CrossRef]
6. Tendeku, D.K.; Akudugu, M.A.; Dittoh, J.S. The Effects of Participation in Smallholder Irrigated Agriculture in the Bawku Area of Ghana. Int. J. Irrig. Agric. Dev. 2017, 1, 44–74.
7. Moari, S.I.; Akudugu, M.A.; Dittoh, J.S. Determinants of Adoption of Ecosystem-Friendly Farming Practices for Sustainable Agricultural Development in Ghana. Int. J. Irrig. Agric. Dev. 2017, 1, 118–131.
8. Smith, J.; Todd, P.E. Does matching overcome LaLonde’s critique of nonexperimental estimators? *J. Econ.* 2005, 125, 305–353. [CrossRef]
9. Dube, K. Implications of rural irrigation schemes on household economy. A case of Lower Gweru Irrigation Scheme, Zimbabwe. *S. Afr. J. Agric. Ext.* 2016, 44, 75–90. [CrossRef]
10. Woodhouse, P.; Veldwisch, G.J.; Venot, J.-P.; Brockington, D.; Komakech, H.; Manjichi, Â. African farmer-led irrigation development: Re-framing agricultural policy and investment? *J. Peasant. Stud.* 2017, 44, 213–233. [CrossRef]
11. Shah, T.; Verna, S.; Pavelic, P. Understanding smallholder irrigation in Sub-Saharan Africa: Results of a sample survey from nine countries. *Water Int.* 2013, 38, 809–826. [CrossRef]
12. Dube, K. Implications of rural irrigation schemes on household economy. A case of Lower Gweru Irrigation Scheme, Zimbabwe. *S. Afr. J. Agric. Ext.* 2016, 44, 75–90. [CrossRef]
13. Heckman, J.J.; Ichimura, H.; Todd, P.E. Matching as An Econometric Evaluation Estimator: Evidence from Evaluating a Job Training Programme. *Rev. Econ. Stud.* 1997, 64, 605–654. [CrossRef]
14. Bertrand, M.; Duflo, E.; Mullainathan, S. How Much Should We Trust Differences-In-Differences Estimates? *Q. J. Econ.* 2004, 119, 249–275. [CrossRef]
15. Jalan, J.; Ravallion, M. Estimating the benefit incidence of an antipoverty program by propensity score matching. *J. Bus. Econ. Stat.* 2003, 21, 19–30. [CrossRef]
16. Gilligan, D.O.; Hoddinott, J. Is there persistence in the impact of emergency food aid? Evidence on consumption, food security, and assets in rural Ethiopia. *Am. J. Agric. Econ.* 2007, 89, 225–242. [CrossRef]
17. Verbeek, M. *A Guide to Econometrics*, 5th ed.; Wiley: Hoboken, NJ, USA, 2017; p. 520. ISBN 9781119401155.
18. Hamilton, L.C. *Statistics with STATA*; Cengage: Boston, MA, USA, 2013; ISBN 9780840064639.
19. Pinzon, E. *Thirty Years with stata: A Retrospective*; Stata Press: College Station, TX, USA, 2015; ISBN 9781597181723.
20. Bittman, F. *Stata—A Really Short Introduction*; DeGruyter Oldenbourg: Boston, MA, USA, 2019; ISBN 9783110617290.
21. Lipton, M.; Litchfield, J.; Faurès, J.M. The effects of irrigation on poverty: A framework for analysis. *Water Policy* 2003, 5, 413–427. [CrossRef]
22. Lipton, M. Farm water and rural poverty reduction in developing Asia. *Irrig. Drain.* 2007, 56, 127–146. [CrossRef]
23. Hussain, I. Direct and indirect benefits and potential disbenefits of irrigation: Evidence and lessons. *Irrig. Drain.* 2007, 56, 179–194. [CrossRef]
24. Hussain, I. Poverty-reducing impacts of irrigation: Evidence and lessons. *Irrig. Drain.* 2007, 56, 147–164. [CrossRef]