Current Investigations in Agriculture and Current Research
DOI: 10.32474/CIACR.2021.09.000309
ISSN: 2637-4676
Research Article

Irrigation and Productivity: Empirical Insight of Farming Households in Tchien District

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Received: February 16, 2021 **Published:** February 26, 2021

Abstract

The study analyses the efficacy of rainfed and irrigated smallholder farms in Tchien district of Liberia. A total of 120 respondents were randomly selected from 5 rural communities around the major rice-producing areas of Tchien District: Gaye town, New Zleh, Old Zleh, Turglor, and Ziah. A total of 58 irrigation farmers and 58 rainfed farmers, comprising of 61 male and 57 female rice farmers were interviewed. Respondents were randomly drawned from a pool of existing Fadama data in Liberia. The study is empirical, taken under different variables to decide the appropriate agricultural system, and the variables to be employed in determining a successful production system. The study applies both the stochastic frontier analysis (SFA) to determine the efficient utilization of production inputs, and the logit model was used to measure the adoption of an irrigation system. Findings suggest that there is a serious disparity in efficiency between rainfed and irrigated farms, implying that irrigated farms are twice as efficient as rainfed farmers; most of the farmers are likely to adopt irrigation systems. Concerned institutions should work to improve access to capital, encourage irrigation farming, and work to effectively integrate experience farmers with young farmers.

Keywords: Production systems; food security; technical efficiency; adoption

Introduction

In the developed world, crop yields are significantly better in irrigated lands than in rainfed areas (Jin et al, [1]). Around 17 percent of the world's agricultural land is irrigated, producing around 40 percent of the world's overall grain output (Jin., et al [1]). Irrigation's effect on poverty alleviation is both direct and multiplier effects. The direct advantages of irrigation could be increased farm productivity as a result of increasing crop yields and diversifying crop patterns and crop technologies. These lead to higher household income, increased spending, and job opportunities. Also, indirectly, it benefits the landless by higher incomes to the degree that irrigation results in higher sold surpluses and expanded job opportunities). Lastly, with the United Nations SDGs, irrigation may contribute to lower food prices (Especially in vulnerable parts of the world) which are especially advantageous to the poor because they expend a relatively significant proportion of their income on food.

Access to irrigation water is widely seen as a key driver of the significant growth gains achieved in Asia in the 1960s and 1970s (Jin et al, [1]). Irrigation's role in agricultural production is widely recognized. More than 324 million hectares or 21 percent of the world's croplands are currently Irrigated (FAO, [2]; Büyükcangaz, et al. [3]). Given the recent increases in food prices, increasing demand for food due to the increasing world population, and the growing need for non-agricultural land use, it is more important now than ever to increase agricultural productivity (Jin, et al., [1]). Developing nations whose economy is mainly agrarian and dependent on traditional agricultural practices are frequently faced with the struggles of poverty and food security and are within the proximity of oblivion, especially within the context of any sudden downturn in rainfall. Subsaharan Africa (SSA) like other developing parts of the world is threatened by earlier aforementioned characteristics, after more than a 15-year downturn in public irrigation spending, there has been a significant spending priority on irrigation (Faures, Svendsen, and Turral [4]). To sustain the MDGs (Millennium Development Goals achieved thus far in the form of the United Nation's Sustainable Sevelopment Goals-SDGs) and other accepted goals on poverty alleviation and food security, rapid-agricultural-production in Subsaharan Africa (SSA) is needed.

In the course to strengthen the policy discussions on the most advantageous and appropriate investment in the SSA context (Lankford [5]), recent studies have centered on the existence and limitations of SSA irrigation growth (Inocencio et al, [6-9] Many Afro-Centric Research & Policy projects have run in tandem with the Agricultural Development Program (CAADP), a continent-wide program created under the NEPAD initiative of the African Union (NEPAD). (Lankford [10]; Inocencio et al. [6]; AfDB et al. [11]; AgWa [12]). The Strategy is based on four grounds, the first being 'sustainable land management and efficient watershed waters (NEPAD [13]). SSA has also established new aggressive national policies for investing in irrigation (GOK 2015 on Kenya; URT 2013 on Tanzania; Républica de Moçambique 2015 on Mozambique). Their efforts were focused on irrigation, and more generally, agricultural water supplies, both from bilateral and international donors (Giordano et al. [14]; World Bank [15]). Reinvestment in the agriculture sector, particularly the SSA, where agricultural production has stagnated in recent decades, was called for in the 2008 World Development Report (World Bank [16]; Woodhouse et al . [9]). During the same year, the 2008 food crisis also reminded the world that African agriculture has not been able in the last two decades to increase its productivity. An agreement of five leading international bodies called for significant new irrigation projects (AfDB et al. [11]). Irrigation is now back on the agenda. Nevertheless, given these lobbying efforts, there is a tendency to believe that a major improvement of the irrigated region requires large-scale investment. In addition to government funding, there are especially strong expectations of large-scale private (foreign) funding (e.g., World Bank of [17]).

Several studies on irrigation have been undertaken in West Africa; Asad and Ismail , carried out a survey to analyze the performance of small scale irrigation technologies such as Californian (PVC pipe layout) and drip irrigation systems with the traditional bucket method is compared in six Sub-Saharan African countries, their findings suggest that California Drip system is more effective than other traditional systems, Liberia was not a part of this study. Buyucangaz et al. [3] Using secondary data, focused on modernized irrigation technologies and systems that utilize less water. The study considers Ghana and Liberia, the findings suggest that both countries have huge irrigation potential. Katic et al., also worked on rice and irrigation in West Africa, even though their findings have high reaching policy implications, they were carried out within the borders of Ghana, Burkina Faso, and Niger, again Liberia is exempted. Therefore, the most important research problems, as it concerns micro studies, in respect of Liberia are addressed in this study. In this paper, we seek to answer the following questions is there any considerable difference in yield between irrigated farms and rainfed farms in Tchein district? If so, what are the difference in the productivity of rainfed farms and irrigated farms? Lastly, what are the factors that determine whether a farmer will adopt irrigation or not? Answers are proffered using cross-sectional data set of farmers in Liberia to examine the practicality of Irrigation amongst small-scale farmers. We analyze some of the latest approaches used to determine the economic benefits of water access; according to their benefits and inconveniences. Based on our sample data collection, we are proposing an enhanced methodology for assessing irrigation productivity effects for Liberia.

The historical development of agriculture in Liberia can be summarized into two: Pre-civil war agricultural Liberia, and the Post Civil war Agricultural Liberia. In pre-civil war Liberia, agriculture accounted for around 40% of GDP, and Liberia was a manufacturer and exporter of essential products-primarily raw timber and rubber (FAO, [18]; Buyukcangaz et al, [3]). The rubber industry produced more than US$ 100 million in annual export earnings. By the end of 1996, the actual GDP was as small as 10% of its pre-war level. However, post-civil Liberia saw growth in rice, timber, and rubber demand, recording a remarkable GDP value of US$ 442 million in 2002. Rainfed agriculture is the prevalent form of farm practice in Liberia. The use of water management equipment is extraordinary and consists mainly of unchecked manual irrigation using watering cans (Woodhouse et al., [9]).

Description of prominent irrigation systems in Liberia

Shallow groundwater irrigation system

Relatively wet valley bottoms are predominant in areas usually dry during the year and are known as agricultural intensification sites in different SSA countries (Woodhouse et al). A low-floor irrigation method is known for its success, extending from central Africa to eastern and southern Africa and a couple of western regions of Africa. The farmers draw water either from the natural drain, excavated to a depth between 1.5 and 5.0 m, between 1.0 and 2.5 m, in the middle of the shallow wells. To add water to the ground, water can and tray pumps are used. Irrigation channels can be formed for the pumping of wastewater during the rainy season. There is standing water in some areas, particularly where a dam or bridge is constructed, which can be used to fish, bathe, or wash clothes. The crops expand on the residual soil moisture during the early dry season, but the majority of farmers start watering their crops from the reservoirs by June and July, according to the position of their soil and the crops being grown. The only downside is that the primary drain is fully drained and the water level has been lowered by more than 2 m below the field level in most wells at the end of the dry season.

Gas PUMP and Irrigation in clear and shallow surface waters

During the past two decades, gas pumps have become popular as an irrigation method used by small farmers to draw water from open reservoirs like lakes and rivers for the intensive cultivation of horticulture. The petrol pumps are irrigated from open and low water supplies. Findings from around the SSA suggest that the pattern is widespread (Giordano et al.[14]). Improved oil pump availability over the last 20 years has been a key factor in the growth of commercial horticulture production and driven by the demand by farmers and rising supply by agritourism networks in municipalities. Local retailers' pumps are sold in the market for a range of prices (US$ 180–570) and sizes (HP 2.5–7). Cheap Japanese pumps have made pumps inexpensive for all, but some farmers invest in cost-effective and efficient pumps (and even to achieve status) (Woodhouse et al., [9]).

(Peri-)Urban wastewater agriculture

Increased demand for fresh fruit and vegetables has increased the local production in almost all urban centers in Africa (Drechsel and Keraita, [19]) and is largely met by the smallholders that operate in an unregulated market. These often include the use of freshwater, whether filtered or not, which poses a substantial security risk to both those who handle the water and for consumers who purchase the irrigation products. Despite this and other risks, small-scale farmers have developed large irrigated areas and frequently move around to new development sites as construction projects drive them from their property.

Materials and Method

Data sources

A data survey was conducted in the Grand Gedeh County of Liberia. The Grand Gedeh County has lower tropical forests that have mid-size hills composed of various valleys and watercourses. The uplands have enormous potential for the intensification and diverse form of agricultural production due to their specific and conducive characteristics: fertile soils, high water concentration, and lower risk of land/environmental degradation for rice cultivation. However, this potential varies immensely across the County: the upper lying areas are conducive for rice production, the low-lying areas are conducive for yam, cocoa, plantains, potatoes, vegetables, rubber, coffee, and sugarcane (FAO, [2]). A total of 120 respondents were randomly selected from 5 rural communities around the major rice-producing areas of Tchien District: Gaye town, New Zleh, Old Zleh, Turglor, and Ziah. A total of 58 irrigation farmers and rainfed farmers, comprising of 61 male and 57 female rice farmers were interviewed.

Method of data analysis

Technical efficiency

Agricultural technical efficiency depends on several variables, such as technology use and relative factors abundance, systemic shifts in market conditions for income and production, economies of magnitude and scope, management systems, specialization in agriculture, etc. (Gorton – Davidova [20]; Swinnen, [21]; Bojnenc et al.,). Several econometric approaches have advanced in the calculation of technical efficiency, stochastic Frontier Analysis(SFA) functions and Data envelopment (DEA) are the two most used in this regard. Particularly in studies of farm-level results, where calculational errors, missed details, temperature, etc are usually play a significant part, the SFA (Coeli, [22]) is suggested. The SFA output function is currently defined as the general shape compound error model:

$$ln\,(Y_i) = F(X_i;\beta) + \epsilon_i \; i = 1,2,3\ldots,N \quad (1)$$

where is the ith farm output; is the ith farm vector of input volume employed to produce any amount of output; β is a vector of unknown parameters which will be estimated; F(.) depicts an appropriate function, (could be transcendent-logarithm, Cobb-Douglas, etc.), and is the term error which is a combination of . is a non-negative variable that represents the model's inefficiency in production relative to the stochastic frontier. Where is an asymmetric error that accounts for random variations in output due to random uncontrollable factors, e.g. weather and pest and disease outbreak, market fluctuations. Both are adjudged to be independently and identically distributed as N(0,). The two-parameter gamma distribution models were also proposed by Greene (1990) and Gujarati (1995). The method for decomposing the error term ε into using conditional distribution of given ε was defined by Jondrow and others (1982) and Mubarik & Flinn (1989). Finally, the SFA equation is typically calculated using the MLE method, regardless of its practical shape.

Some studies carried out the dual-stage MLE Stochastic Frontier Function, and subsequently regressed obtained technical/economic efficient variables against some social and economic variables: farmers' educational level, farmer's age, farm-scale, etc to assess inefficiency(s) contributions of these variables (Mubarik and Flinn [23]; Deb and Hossain [24]; Parikh et al. ; Coelli and Battese [25]). Nevertheless, the two-stage approach has been argued to have a major problem (Kumbhakar, [26]) and Reifschneider and Stevenson [27]. This means that in the second stage, the presumption that the inefficiency effects are distinct and identically distributed is violated when they are made to depend on several different farm unique factors and not on the non-identical distribution.

Specification of the model

Following the Approach of Manyong et al [28], a stochastic production function analyses individual farm economic efficiency, its formulation follows Coelli and Battese's [25] inefficiency model. The key difference is the influence of inputs on performance in the different socio-economic domains that are specifically incorporated into the development cycle by a methodology of a fixed effect where every stratum has a dummy variable that measures their impact on a certain domain (Hoch 1958). This approach eliminates problems with missing variables and the dummies can be used as an indicator of technical performance since the relationship between output and fixed results are thus established (Hoch [29]).

$$ln\,(Y_i) = \sum \partial (S_i) \sum \beta_i ln(X_{pi}) + v_i - \mu_i \quad (2)$$

where are dummy intercepts dummies; i subscript refers to the ith farmer; ln is the natural logarithm, is the total value of the output of the ith farmer in Liberian Dollars; are input variables.

The technological efficiency of a farmer is specified as the ratio of the production observed to the frontier production that could be generated by a 100 percent farm with zero inefficiencies. In the log format of the equation (Battese and Coelli [30]; Battese and Coelli 1993), this has been seen to be mathematically calculated as:

$$TE_i = exp(-\mu_i) \quad (3)$$

The above equation restricts the technological efficiency of each farmer to values between zero and one, which is inversely related to the inefficiency effect. Subsequently, however, and more accurately, we respond to the effects of the boundary function in terms of economic efficiency rather than just technological efficiency. The variables used for this study include Farm sizes in hectares, Labour in man/day, Credit use, Fertilizer use, other expenditure variables like seeds, pesticides, traction.

Logistic Regression

Logistic regression is a binary paradigm (Tourenq et al. [31]; Conteh et al . [32]) commonly used in acceptance trials (Pattanayak et al. [33]). For this study, a logit model was defined to answer the decision of the farmer to follow irrigation or otherwise. Let be the decision of the farmer to obey the irrigation alley or not, and let x be the vector of the explanatory variables for that decision. Vector can also be a variety of factors (e.g. socio-economic characteristics and land ownership rights). Under the aforementioned scenario, the decision of the farmer to seek irrigation shall be articulated as follows:

$$\varphi = F(X, \varepsilon) \quad (4)$$

Where is the error term, and is also a vector?

A conceptual mathematical model representing the above-mentioned logit function can be described (following Chieh-Hua and Koppelman [34]; Jones and Branton [35]; Liao and Khew-Voon [36]) as follows:

$$\varphi_{ij} = F(I_{is}) = \frac{e^{S_{is}}}{1+e^{S_{is}}}\text{, where } S_{is} \text{ is a function of } X_{is}\emptyset_{is} \text{ and } -\infty < S_{is} < +\infty \quad (5)$$

Where is the dependent variable whose value alternates between 0 and 1: zero (0) for no-irrigation and one (1) for the adoption of irrigation by the ith farmer in the ecotone; is the matrix of explanatory variables for the farming technology adopted in the kth ecotone; is the approximate range of parameters; and is the implied adoption measure. The model will be estimated using Stata 14 program under the Maximum Likelihood Estimator (MLE).

Result and Findings

A total of 120 farmers were interviewed in the Tchien district of Liberia. This consists of 58 irrigation users and 58 rainfed farmers and 2 bad observations. The average literacy rate of farmers in the region was 6 years for rainfed farmers and 5 years for irrigated farmers, this implies that the majority of the farmers are literate thanks to different educational dissemination and informal education programs which have seen a more beneficial increase in rural education in Liberia (UNESCO, [37]). The average age per farmer was 47 years for rainfed and 45 years for irrigated farmers respectively, this shows that the majority of the farmers are within the mean of productive age. Farm experience varies greatly between the rainfed (27 years) and irrigated(23years). The average total land size cultivated is 1.6 ha acres for rainfed farms and 1. 53 ha for irrigated farmers. in Tchein region with the annual average income per hectare being Liberian Dollar 2298.20 for rainfed farmers and 2023.03 for irrigated farmers. The average labour in man-day used on rainfed farm was 4.5 hours (4.47) and 4.3 hours (4.31) for an irrigated farm. this suggests that although rainfed farms utilize more man-day labour per hour (0.16) on average than irrigated farms, farming in Tchien region is pretty much labour intensive. the average farm expenditure varies largely between rainfed (601.75 Liberian Dollars) and irrigated farms (1348.17 Liberian dollars), this can be explained by the high initial cost associated with irrigation equipment. The total yield varies by the farming system, this disparity is a suggestion of the difference in the farming system as both farms cultivate the same crop(rice).

As the major aim is to maximize yield by minimizing the input variable cost, the summary statistic as preliminary information indicates that smallholder farmers in the regionwould opt for an irrigated farm. Deducing from the preliminary information in Table 1, it can be observed that although the expenditure incurred by irrigated farms more than doubled that of rainfed farmers, it is compensated for in the yield of irrigated farms which despite having a smaller cultivated land size, lower labour input is higher than that rainfed farmers. Since smallholder farmers are well informed of development within their locality, it can be posited that the equal income arising from both activities will largely sway most rainfed farmers to consider a change of system. The preliminary findings are supported by FAO (2020), where they argued that an improved technology or system no matter how little or small has the potential to improve yield. Table 2. depicts the maximum likelihood estimates of the appraised stochastic frontier production function. Table 2 consists of four main variables: another farm expenditure, cultivated land size, fertilizer, and labour, the model is input cost-oriented.

Table 1: Summary statistics on average production.

	Rainfed farm			Irrigated Farm		
Variable	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.
literacy	60	6,05	3,48	58	5,29	4,08
Age year	60	47,13	12,90	58	44,59	14,19
Households	60	7	3	58	7	2
Farmexperi	60	27,20	14,88	58	23,16	15,22
Totalculiv	60	1,66	1,47	58	1,63	1,53
Farm income $	60	1860,20	2261,55	58	1865,10	2098,16
Farm expend	60	601,75	721,99	58	1348,17	5025,89
Household income	60	2298,20	2284,22	58	2023,03	2150,96
Labour (Man)	60	4,47	2,10	58	4,31	1,85
Total yield	60	195,77	297,74	58	273,47	437,07

Table 2: Maximum likelihood estimates of the stochastic frontier production function.

Production system						
Parameters	Rainfed Farm			Irrigated Farm		
	Coeficient	Std.Error	P-Value	Coeficient	Std.Error	P-Value
Other Exp (Liberian $)	0.465	0	0.000*	0.476	0.064	0.000*
Land (ha)	0.671	0	0.000*	0.301	0.158	0.051***
Fertili (kg)	-0.094	0	0.000*	-0.026	0.153	0.864
Labour (Manday)	0.976	0	0.000*	0.131	0.115	0.256
Constant	5.397	0	0.000*	4.2	0.816	0.000*

*p < 0.10, **p < 0.05, ***p < 0.10.

The result suggests that other farm expenditure is statistically significant at 1%, The positive and significant coefficient for other Exp (Liberian $) of 0.465 implies that farm income or income from yield is positively elastic suggesting that a 1 Liberian $ increase in other expenditure will bring about the elasticity of 47% in farm income. This happens when there are proper allocation and usage of funds. These findings agree with the works of Browne et al [38], where they found that expenditure is positive and always implies growth.

The estimated coefficients of land (ha) size for rainfed and irrigated farming are positive and significant at 1% and 10% respectively. The coefficient of land for rainfed of 0.67 and 0.30 for irrigated farms, indicates that yield output is proportional to the change in land size. A 1% increase or change in the land (ha) should induce about 67% in rainfed farms and 30% in irrigated farms correspondingly. The findings are parallel with Mango (2015), Amaza and Olayemi [39], and Coelli and Battese [25]).

The coefficients of fertilizer in kg for rainfed and irrigated farms both are negative. Rainfed's coefficient is negative and significant at 1%, which means that a 1% change in fertilizer(kg) would negatively influence yield by a coefficient of -0.094 rainfed farms and is statistically. A 1% change in kg of fertilizer would negatively reduce the total irrigated farms by a coefficient of -0.026, however, is statistically insignificant at all levels. Thus, the findings suggest that the smallholder farmers in Tchein district are using fertilizer inefficiently, and continuous usage without correction would eventually wipe out whatever efficiency they might have gained from other factors of production. Besides, the most dominantly used fertilizer in rice production in developing countries remains synthetic fertilizer (Harrison, [40]) Inefficient utilization of fertilizer, and continuous utilization of inorganic fertilizer has been found to affect soil adversely (Shambhavi, et al, [41]).

The labor coefficient is elastic at 0.976, which means that a 1 % rise in labor (man-days) will result in a 98% improvement in output. Hence, labor acts as a backbone or engine of small farmers in rainfed areas. Smallholder uses labor-intensive, which verifies the findings of Mango et al, 2015 based on maize production in Zimbabwe. Consequently, smallholders would prefer maximizing labor-intensive or output to accentuate technical efficiency in a rainfed farm. The inefficiency model in Table 3 gives some insights into factors affecting technical efficiency. A negative sign on a parameter means that the variable reduces technical inefficiency while a positive sign increases technical inefficiency. The age of a household head is observed to have a negative coefficient indicating that older farmers are more technically efficient than younger ones. This agrees with the work of Li and Sincular [42] where they observed that household-level technical efficiency increases until maximum efficiency is reached when the average age of the household labor force is 45, after which efficiency declines. Also, access to capital decreases the technical inefficiency of both rainfed and irrigated farms. This agrees with the apriori expectation that access to credit should transform into productivity, but access to credit does not necessarily mean judicious utilization of credit; it has been well documented that farmers upon getting credit seldom use the credit for agriculturally related endeavors (Christeansen, [43]). The use of insecticide is statistically significant and improves technical inefficiency in Tchein region of Liberia. However, the findings of Abedullah et al., [44] suggest that in areas of high pest infestations, using insecticides can greatly improve technical efficiency: albeit due to environmental and health concerns, insecticides are not recommended.

Table 3: Factors affecting production technical efficiency.

Production system				
Inefficiency effects	Rainfed Farm		Irrigated Farm	
Parameters	Mean coefficient	Std.Error	Mean coefficient	Std.Error
Age	-1.098	0.803	1.486	3.092
farm exp	3.093	0.296	-1.051	0.944
access to capital	-0.045	0.361	-1.759	2.07
insecticide use	0.069	0.291	1.245	0.7
Constant	3.378	2.285	-3.974	8.95

Logit analysis

The outcome of the study reveals that the regression chi-square is 34.61, which is statistically significant at 1%. The model has a negative Log-likelihood of-62.476548 representing a model with a strong fit and a reasonable distribution of the error term. Variables that had significant coefficient s are age, farm income, income from off/non-farm activities, total yield (at 5% level of significance), and total cultivated area (at 10% level of significance). Some of the coefficients are positive while some are negative. A positive coefficient implies that higher values of such variables tend to increase the farmers' probability of irrigation. Similarly, the negative value of the parameters means that the higher value of the variables will minimize the farmer's probability of irrigation (Table 4).

Table 4: Logit analysis of production system selection.

No of Obs=116				
LR Chi2(14)=34.61				
Prob>Chi = 0.007				
Log likelihood= -62.4766		Pseudo R2 =0.2169		
Irrigation user	Marginal effect	Standard error	Z	P>|Z|
Gender	0,0097	0,4715	0,09	0,926
Age(years)	-0,0086	0,0183	1.97*	0.049*
Marital status	-0,1705	0,2268	1,55	0,12
Farm experience	-0,0016	0,0168	0,41	0,683
Farm Income	0,0001	0,0001	2.44*	0.015*
Income from Nonfarm act	-0,0002	0,0005	2.21*	0.027*
Extension contact	0,0538	0,587	0,51	0,611
Credit Utilization	0,8933	0	0,01	0,991
Access to training on Irrigation	-0,8126	0,0002	0,01	0,99
Total Yield	0,0004	0,0009	2.22*	0,026
Soil fertility	-0,0963	0,4056	0,67	0,503

Pest and insect infection	0,1917	21,507	1,16	0,247
Education	0,14	0,90328	1,31	0,189
Total cultivated	0,1109	0,1634	1,82	0,689
Const		37,333	0,51	0,61

Age is significant and had a negative coefficient meaning that an increase in the age of the farmer will decrease the probability of using irrigation. An increase in the unit age of a farmer will reduce the probability of farmers using irrigation by 0.86 percent. This suggests that relatively older farmers are risk-averse and are usually conservative, this is supported by the findings of Heanue, et al., [45], where they find that age has a negative effect on adoption in Ethiopia. The income from off/non-farm activities has a negative coefficient as significant. This result is contrary to apriori expectation. Nonetheless, traditional farming is a labour intensive endeavor, most farmers pride themselves on their occupation, it is only rational that they do not engage in off-farm occupations it will imply less time spent farming. The cultivated land size was found to negatively influence the probability of adopting irrigation. This finding agrees with the work of Ntshangase, et al., [46], where they found that cultivated land size could be negative or positive because management practices may not be sustainable on larger pieces of land. Both farm income and total yield have positive coefficients and are significant (at a 5 percent level of significance). This implies both variables will increase the probability of farmers using irrigation in cultivating their lands. An increase in a unit of farm income will increase the likelihood of the farmer cultivating his piece of land using irrigation by 0.0069% while that of total yield will increase by 0.043%. The finding is supported by the intuition that farming like every other business is profit-oriented, thus any possibility of innovation increasing the likelihood of profit is likely going to sway adoption positively. This intuition is supported by the findings of Sauer and Zilberman [47-50].

Conclusion and Policy implication

Given a fastidious and incisive analysis of factors and production systems implemented in Liberian farming activities, the study has shown that deviation in the yield across the production system in Liberia is due to differences in their technical efficiency levels. From the findings, Irrigated farms are more technically efficient than rainfed farmers. On the adoption of irrigation as a farming system, the study suggests that acceptance of irrigation as a new farming method in the community will have an impact on its continued promotion and existence in the community [51-55]. Socioeconomic factors such as age, off-farm income, cultivated land size, farm income, and farm yield are important determinants in the process of irrigation adoption in the region.

Despite the continued effort from the government of Liberia, and other NGOs to invest in the Liberian agricultural sector through agricultural input subsidies, extension services, and promotion of new technology, small-scale rice farming has remained technically inefficient in the Tchein region. Three policy issues emerge as a result of this study. Firstly, given the positive effect of access to capital on efficiency, it is quintessential that great emphasis is placed on the agricultural development strategy to focus on creating an environment that facilitates farmers to continue to promote improved access to rural finance. Secondly, given the positive effect of age to the government must recalibrate the extension and policy focus to assist old farmers with a miss of young farmers, so that the latter can learn from the former. On adoption, it is obvious that irrigation adoption is still met with some skepticism—given the numbers of farmers that are practicing rainfed farming--and the irrigation system found in the Tchein region is far from advanced, the government does have a role to play in diffusion and in encouraging adoption of irrigation into the region.

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DOI: 10.32474/CIACR.2021.09.000309