Invited paper presented at the 6th African Conference of Agricultural Economists, September 23-26, 2019, Abuja, Nigeria

Water security impacts on smallholder agriculture in the Sisili-Kulpawn Basin of the Northern Region of Ghana

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Abstract

Background: This study analyzes the impacts of water security on smallholder agriculture in the Sisili-Kulpawn Basin (SKB) of the Northern Region (NR) of Ghana. Purposive sampling was used to sample 200 households which comprised of 100 irrigators and 100 non-irrigators. The study used the Water Poverty Index (WPI) approach to assess the level of water security in the study area. The study also deployed the Ordinary Least Square (OLS) regression to estimate the economic impact of household water security on smallholder agriculture.

Results: The findings of the WPI model indicated that only Yagaba (57.2%) was water secured whilst Loagri (47.6%), Kunkwa (25.2%) and Wiasi (28.4%) were water insecured areas. The results from the OLS model indicated that Education, credit access, irrigators, shocks and number of extension visits were all positively significant indicating higher water poverty index.

Conclusion: Smallholder farmers are faced with the challenges posed by the erratic nature of rainfall and unpredictable flooding of farms at the lowlands by the Sisili-Kulpawn Basin (SKB). Farmers who farm the uplands are faced with long period of drought during the dry season. Climate change if not mitigated will increase the vulnerability of these smallholders by worsening their challenges and this will elevate poverty levels.

Key words: Water Security, Climate Change, Water Poverty Index, Northern Region

Introduction

Globally, the application of water and its use has been an essential factor in increasing agricultural productivity and ensuring greater outputs. Sustainable water management helps to ensure better production both for direct consumption and for commercial purposes, so enhancing the generation of necessary economic surpluses for uplifting rural economies.

In Ghana, water resources play a central role in enhancing living standards, economic growth, provision of food security and livelihood, and eventually alleviation of poverty. Unlike most countries, Ghana is experiencing population growth and associated demand on food production. Therefore, demand on water increases steadily while producing stress on available water resources.

Inefficient water resource development and conservation systems suitable for smallholder farmers are some of the major problems limiting the capacity of agriculture to meet its role in food security and overall development in the country. Improvement of the water use efficiency is therefore important as long as agriculture is concern.

Agriculture in Ghana is largely rain-fed and it is mainly dominated by the rural people who lack the resources to adapt to the consequences of climate change. This makes the agricultural sector in Ghana exposed to more risk. Hence, the irregular nature of rainfall and the uncertainties about climate change will further worsened the concerns of rural people who rely on the agriculture sector.

Small multi-purpose reservoirs are usually regarded for irrigation purposes. In the rural areas of Ghana where surface water is scarce, reservoirs are used for daily activities to improve the livelihood of the people. Northern Regions of Ghana where there are irregular rainfall patterns, small dams are mostly considered to ensure a year round growing season and also water supply for livestock and domestic purposes as well.

Climate studies have been conducted in Ghana and the reports have shown distinctive inter-annual and inter-decadal changes in major agriculturally-relevant climate variables such as temperature and rainfall (Challinor, *et al.*, 2007; De Pinto *et al.*, 2012; Amikuzuno and Hathie, 2013). In the Northern Region of Ghana, this phenomenon may have adverse implications on yields and hence livelihood of the rural poor.

In Ghana, the three Northern regions have been widely designated as the poorest regions and the impacts of climate change are expected to be much more severe in these regions. Crop failure due to irregular rainfall patterns has been reported in recent times in the regions (Amikuzuno and Donkoh, 2012).

To identify the empirical gaps of previous studies, this study seeks to quantify the potential economic impacts of water security on agricultural production, adaptation strategies to manage water insecurity, and constraints faced in the SKB of the Northern Region of Ghana. The purpose is to assess how water security, with or without adaptation, will affect livelihood and how farmers respond to these impacts through the implementation of adaptation strategies that promote their resilience. There is a gap between farmers' knowledge and water management technologies in the SKB. This study particularly, seeks to examine how farmers' wellbeing might be affected if future water insecurity issues are curbed.

Study Area and Data collection

The Sisili-kulpawn Basin is a catchment area located in the Mamprugo-Moaduri District (MMD). On 28th, June, 2012, the district with its capital as Yagaba was carved out from West Mamprusi District.

The major drainage feature of the district is the White Volta Basin and its main tributaries such as the Sisili and the Kulpawn rivers. Along the valleys of these rivers are large arable land that is suitable for the cultivation of rice and other cereals (MMD Assembly, 2013
).

The SKB is characterized by difficult agro-ecological conditions, such as annual flooding, drought periods, poor soils, erratic rainfall, exacerbated by the adverse effects of climate change. Recent investigations into the scenarios for development of water management and irrigation and drainage practices have demonstrated that there is a great potential for large scale irrigation in the North (IWAD, 2013).

The sampling procedure that was considered in this study was a multi-stage purposive sampling procedure. Firstly, SKB is selected as it is identified as one of project intervention areas as in the IWAD project. Four communities were purposively selected namely; Loagri, Gbima, Iziasi and Wiasi representing two irrigation and non-irrigation communities respectively. The stratum of irrigation user consists of households who have access to irrigated land for direct utilization. The second stratum referred to hereafter as non-users composed of households who do not have access to irrigated land. In the second stage, farm households consisting of 100 irrigation users and 100 non-users were selected using simple random sampling technique.

Both primary and secondary data collection methods were employed. The primary data required for this study were collected using questionnaires. The data collection started after pretesting and modifications. The field specific questions were collected based on the conditions that prevailed during 2015/2016 production year.

Methods of Data Analysis

The composite index approach is used to calculate the Water Poverty Index (WPI). The five key components are combined using the general expression:

$$WPI = \frac{(\sum wiXi)}{(\sum wi)} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots .1$$

Where WPI is the Water Poverty Index value for a particular location,

Xi refers to component i of the WPI structure for that location, and wi is the weight applied to that component. Each component is made up of a number of sub-components, and these are first combined using the same technique in order to obtain the components. For the components listed above, the equation can be re- written:

$$WPI = \frac{(wrR + waA + wcC + wuU + weE)}{(wr + wa + wc + wu + we)} \dots\dots\dots\dots\dots\dots\dots\dots\dots.2$$

The above equation is the weighted average of the five components Resources (R), Access (A), Capacity (C), Use (U) and the environment (E) Each of the components is first standardized so that it falls in the range 0 to 100; thus the resulting WPI value is also between 0 and 100. Values of 50% approaching 100% indicates higher water poverty index whiles values below 50% are indicating lower water poverty index hence water insecurity.

The Water Poverty Index Pentagram was further used to display in an accessible way that will give a clear picture of each of the components.

In order to estimate on the economic impact of household water security on rural farm household livelihoods, total monthly household income as an economic poverty indicator is considered. This is because income is an indicator of household welfare and also for simplicity and availability of data (Myles and Garnett, 2000; Kuan and Osberg, 2002) and Osberg and Kuan, 2008. The empirical analysis consists of estimating an equation for income, with water poverty indices as one of the independent variables. Specifically, this is premised on the estimation of the following equation

$$\text{Income}_j = \propto_0 + \propto_1 \text{Access}_j + \propto_2 \text{Capacity}_j + \propto_3 \text{Use}_j + \alpha_4 \text{availability}$$

$$+ \alpha_5 \text{environment} + a_5 Z_j + \varepsilon_j$$

For j = 1......, 200 rural households. The vector $\mathbf{Z_j}$ consists of explanatory variables such as age, farm size, educational level, farm experience, access to credit, access to climatic information, access to extension services among others. The parameters to be estimated are α_0, α_1, α_2, α_3, α_4, α_5 and a_5. The error term is under the assumption of independent, identical and normally distributed with mean 0 and Standard Deviation 1 (Wooldridge, 2002).

Since income will be measured on a continuous non-zero and non-negative scale, the above equation will be estimated using the Ordinary Least Squares (OLS). To take into account the variation in income levels arising from variations in household size, the income per capita as the dependent variable.

The STATA software package Stata SE 14 version was used for the analysis.

Results and Discussion

Socio-demographic characteristics of farmers

Table 1. Descriptive analysis of sex, marital status and shocks

Variable		irrigators		Non-Irrigators		P value
		Frequency	percentage	Frequency	percentage	
Sex	Male	91	91.00	86	86.00	0.268
	Female	9	9.00	14	14.00	
Marital status	Married	90	90.00	89	89.00	0.818
	Unmarried	10	10.00	11	11.00	
Shocks	Yes	30	27.00	76	74.40	0.000***
	No	60	54.00	22	21.56	

Source: Authors' Analysis, 2017

Out of the total sampled household of irrigators, 91% were male-headed and 9% were female-headed. The chi-square value shows that the proportion male headed households are relatively higher for irrigation participants (91%) than for the non-participants (86%). Majority of the respondents under each category were married representing 90% irrigators and 89% non-irrigators respectively. Household respondents were assessed based on the shocks that were experienced within the last two (2) seasons. The findings revealed that a majority of the respondents (74.40%) who were exposed to shocks were the non-irrigators.

Table 2 Descriptive analysis of continuous variables

Variable	Irrigator	Non-Irrigator	Min	Max	T test
	Mean				
Age	42.34	45.82	20	75	-1.82**
Education	8.15	9.33	0	21	-2.095**
Income from other sources	1463.5	193.78	100	5500	11.283***
Years of experience	19.30	18.26	2	58	0.671
Extension visits	3.49	1.77	0	8	7.200***
Household size	2.81	8.10	1	28	-11.681***
Farm size	8.35	7.71	2	28	0.585
Number of crops cultivated	2.26	3.09	1	4	-9.873***

Amount lost due to shocks (GH)	765.23	986.34	100	3600	-2.458***
Distance from home to irrigated land (m)	61.35		10	302	

Source: Authors' Analysis, 2017

The mean age of the heads of sample respondents was 42.34 years for irrigation users. For non-irrigators the mean age was 45.82 years. The age difference between the two groups is found to be statistically significant suggesting age has influence on the participation decision. This indicates that non-irrigators are averagely older than irrigators. Therefore, with significant critical t-statistic of -1.82, this shows that increasing participation in the small-scale irrigation scheme depend on the farmer's age which is in conformity with Bacha et al. (2011) that age is a very important continuous variable positively influenced household heads decision to participate in irrigation but contradicts the findings of Aregawi (2014).

The summary result presented in the above table suggests mean education level of irrigation user household heads and non-users were 8.15 and 9.39 respectively. The survey result reveals that educated people are associated with non-irrigation than irrigation. It was expected that households with better educational background are more likely to use irrigation.

The average farm experience of irrigation users and non-users were 19.30 and 18.26 years respectively. This indicates that as experience advances, household heads did not become eager to accept irrigation technology. Therefore, with insignificant critical t-statistic of 0.671.

With regard to household size, the average household size per adult equivalent for the small-scale irrigation users and non-users is found to be 2.81 and 8.10, respectively. This result shows that it is statistically significant at 1%. Furthermore, the result of the study revealed that farm size is insignificant. Farm size between the two groups is found to be statistically insignificant suggesting that it has no influence on the participation decision.

Also, number of crops grown by irrigators and non-irrigators were on average of 2.26 and 3.09 respectively and statistically significant at 1%. This indicates that because of marketing purposes irrigators specialize on high value crops than staple crop.

Lastly, with regards to how much is lost to shocks, irrigators and non-irrigators lost an average amount of GH 765.23 and GH 986.34 respectively. This is statistically significant at 1 % level and indicating that as the amount lost due to shocks increases, a farm household respondent is more likely to participate in irrigation

Farm household Water security in the SKB

The Water Poverty Index (WPI) was deployed by the researcher to assess the household water security among smallholder farmers in the Sisili-Kulpawn Basin in the MMD.

Weighting of WPI components

Whiles other researchers have used the Principal Component Analysis (PCA) in the weighting of the WPI components, there have been recent critiques in the weighting by Gine and Perez (2017) and that all variables have equal importance hence the practice of assigning unequal weights to the components does not make sense since there is no evidence that it should be so. So the application of equal weights is done such that the sum of all the weights shall equal one (1). So dividing 1 by the five components, each component is assigned a weight of 0.2.

Table 3 household water security characteristics and WPI in the Sisili-Kulpawn Basin

WPI	**Yagaba**	**Loagri**	**Kunkwa**	**Wiasi**
Weights (0.2)				
Availability	52	36	30	26
Accessibility	40	30	8	22
Capacity	64	38	22	32
Use	100	100	0	0
Environment	30	34	66	62
WPI	**57.2**	**47.6**	**25.2**	**28.4**

Source: Authors' Analysis, 2017

Access:

This component shows access that people have to water for effective use and survival. Sources of water in both communities include wells and rivers. The results show that Yagaba and Loagri has a higher score (40) and (38) respectively on access whiles Wiasi (22) and Kunkwa (8) have lower scores. This is explained by availability of water in some sections of Yagaba and Loagri which increases people's access to water sources. In Kunkwa and Wiasi, households do not have access to irrigated lands. This limits people's access to water for irrigation.

Use:

Use indicators were not reported for non-irrigation household. Yagaba and Loagri are the irrigation which shows that households in these communities are irrigators whiles the Kunkwa and Wiasi communities were not reported because they were non-irrigation communities and hence were not engaged in irrigation activities.

Capacity:

This component indicates people's capacity to manage water resources, based on education and access to financing. Primary education is the level of education of most people in both communities. Their main sources of income include farming and small businesses.

The results show that Yagaba has a higher score (64) on capacity compared to Loagri (38). The higher score on capacity in Yagaba reflects a higher status in ability to manage water sources, and a better educational status than the residents in Loagri (38), Wiasi (32) and Kunkwa (22) which is in conformity with Sullivan et al., (2006).

Water is the major ingredient in irrigation farming. Therefore, involvement of farmers in irrigation agriculture in Yagaba and Loagri increases their income base which in turn increases their financial capacity to adapt good water efficiency strategies to manage water use as this also confirms the study of Kaiyatsa (2014).

Environment:

Irrigation households have higher scores on indicators that enhance their effectiveness to manage water, and also suffer less from environmental problems as in crop losses for the last five years. The results indicated that Kunkwa and Wiasi experienced high crop losses as they represent majority of the respondents of 66 and 62 scores respectively. The measurement of this component was in line with center for Hydrology and ecology (2016).

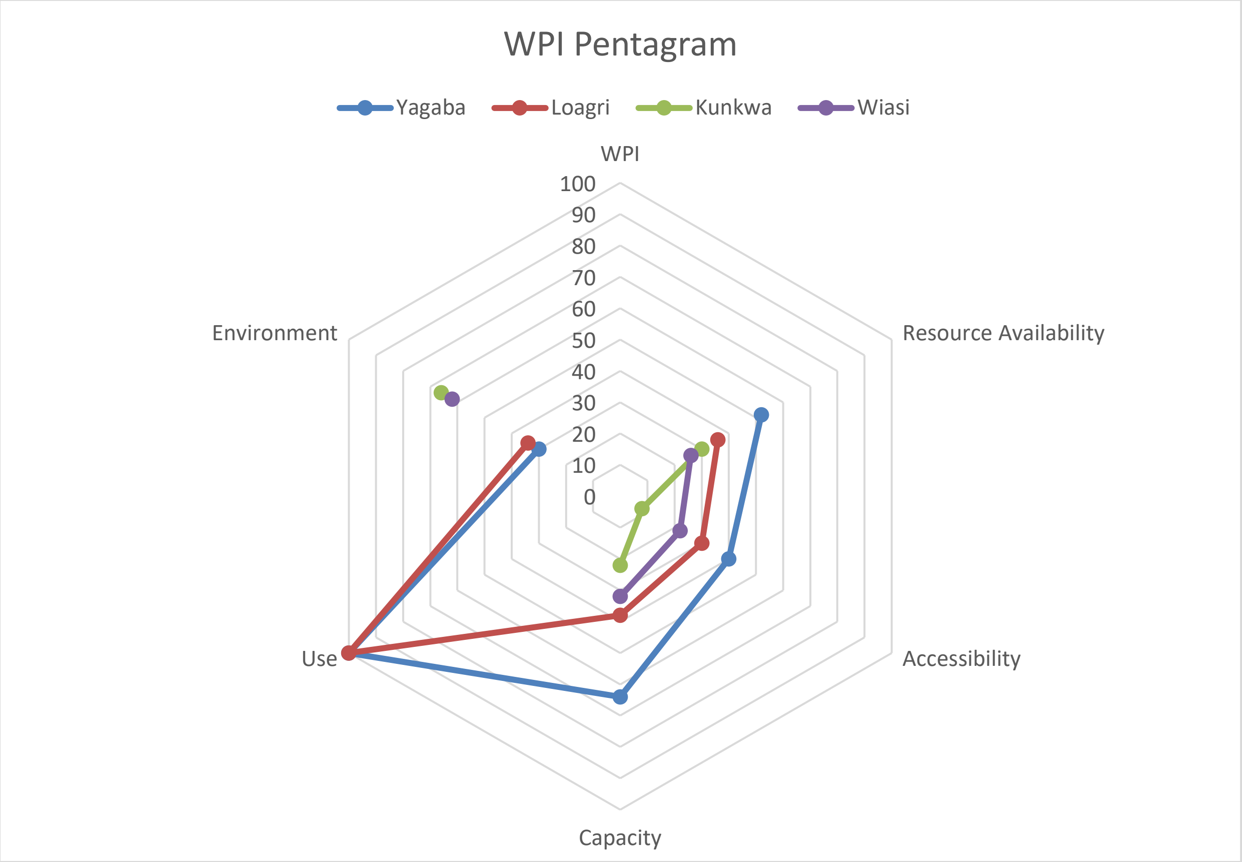
Resource:

This component indicates physical availability of surface and ground water taking into account rainy and dry seasons. The results indicated that resource availability in Yagaba and Loagri is higher than Kunkwa and Wiasi.

The WPI Pentagram

The pentagram presents Kunkwa and Wiasi as the neediest community in terms of capacity, use, access and environment. On the other hand, Yagaba and Loagri are the water secured areas. Consequently, there was a higher water poverty index score for Yagaba and Loagri representing 57.2 % and 47.6% respectively compared to Kunkwa (25.20) and Wiasi (28.4). According Sullivan et al. (2003) the highest value, 100, is taken as the best situation of been water secured while 0 as the worst situation of water security (50-100(water secured), 0-49 (water insecure)). Since water poverty index scores for Loagri, Kunkwa and Wiasi communities are below 50, the level of water poverty in both communities is high. Only Yagaba community is proven to be water secured.

Fig 1. The WPI Pentagram



Source: Authors' Analysis, 2017

Economic impact of household water security on rural farm household livelihood

From the Regression model below, the R^2 is 41% which explains the variation between the socio-economic factors and water poverty with household income.

The primary interest is to examine how water poverty determines economic poverty. Table 4. below shows an OLS regression model for the economic impact of household water security on farm household livelihood.

Income	Coefficient	Std. Error	T	p>[t]
WPI components				
Access	-3.234	0.752	-4.30	0.000***

Availability	0.291	0.152	1.91	0.065*
Use	-4.788	1.253	-3.82	0.000***
Environment	-0.132	1.099	-0.12	0.905
Socio-economic factors				
Age	0.008	0.008	0.97	0.337
Education	-0.011	0.020	-0.53	0.600
Farm size	0.073	0.035	2.10	0.039**
Farm exp.	0.003	0.010	0.28	0.783
Climatic info.	0.159	0.347	0.46	0.649
Credit access	-0.129	0.403	-0.32	0.749
Household size	0.059	0.031	1.87	0.065*
Marital Status	0.299	0.323	0.91	0.367

Table 4. OLS regression for the Economic impact of household water security

Source: Authors' Analysis, 2017

The results from the Model showed that, among the four water poverty indicators, those relating to water access matter significantly for household per capita income. The R ^{2} from the model explains the variation between the socio-economic factors and water poverty with household income.

Specifically, the results suggest that the better the household's access to water, the lower its per capita income. This means that households who have water access are economically poor. This contradicts the findings of Matshe et. al. (2016), Molden et. al., (2001) and the researcher's *a priori* expectation. It was expected that the importance of water access will drive the realized impact of overall water poverty on household income. Molden et al (2001) revealed the crucial role of water access in the welfare of rural households.

The study also revealed that households who have water available in their communities were positively significant to household per capita income. Irrigators were negatively significant at 1% in relation to economic poverty. It was expected that irrigators will have positive relation with per capita income. The control variables suggest that the older the head of household, the higher the household's level of total monthly income. Large household size could give them an advantage in income-generation compared to smaller household size. Also, the results revealed that households with larger farm sizes are associated with higher incomes.

During the analysis, the capacity component among the water poverty indicators was omitted by STATA which showed signs of potential endogeneity between economic poverty and capacity. Wealthier households are likely to adapt good water management technologies.

Conclusion

The results of our study showed that, agriculture in the SKB is predominantly rain-fed where smallholder farmers are exposed to the erratic nature of the climate variables and the consequences that follows. A wide range of rain-fed crops including maize, cowpea, rice, millet and a variety of vegetables are cultivated; among which maize and cowpea are predominantly cropped.

Seasonal flooding of lowlands by the SKB allows the lowlands to be cropped twice; before and after the floods. This allows smallholder farmers to cultivate twice within a cropping season (Early- and late- cropping season). The floods also leave behind relatively more fertile soil which offers farmers the opportunity of increasing their yields.

Despite these advantages, smallholder farmers are faced with the challenges posed by the erratic nature of rainfall and unpredictable flooding of farms at the lowlands by the Sisili-Kulpawn River. Farmers who farm the uplands are faced with long period of drought during the dry season.

In using the Water Poverty Index (WPI) approach to assess the water security levels in the SKB; the study revealed that, smallholder farmers in the Yagaba community was the only water secured community with a WPI of 57.2% whiles Loagri, Kunkwa and Wiasi were water insecured communities representing 47.6%, 25.2% and 28.4% WPI respectively.

The OLS was used as to analyse the economic impacts of water security on smallholder agriculture. The results indicated positive significant values with education, access to credit, irrigators, shocks and extension visits. This implies that household heads who are educated are associated with high WPI, households who have access to credit also had higher WPI. Irrigators were associated with higher WPI than non-irrigators *ceteris paribus*. Interestingly, households who were exposed to shocks were also associated with higher WPI than those who did not experience shocks, *ceteris paribus*.

Due to the high variability and seasonality of the rainfall events, we recommend that access to information on the climate, extension and technological services becomes very crucial. MOFA and other stakeholders like IWAD should be able to assist farmers to know correct timing for planting to reduce loss of crop through flooding and/or delay in rains, encourage irrigation and the use of Good adaptation strategies to curb the insecurity issues. In this regard, smallholder farmers will be able to build their resilience.

Acknowledgements

We appreciate the assistance given to us by the district and the communities involved.

To the teaching Assistants and colleagues of the Agricultural Economics department and Department of climate change of the University for Development studies (UDS), we say thank you.

Not forgetting the creator of heaven and earth, the one who made it possible for us, our Father in heaven thank you for all you have done for us.

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