Impacts of Small-Scale Irrigation Farming on the Environment Within the White Volta River Basin in the Bawku West District of Northern Ghana

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Abstract

Dry-season irrigation farming plays a crucial role in enhancing food security, employment, and income for rural farmers. Northern Ghana experiences a long dry season, making irrigation farming essential for improving the socioeconomic conditions of smallholder farmers in the area. Despite these advantages, small-scale irrigation practices can have negative environmental effects. The White Volta River (WVR) is particularly affected by unsustainable farming practices that degrade water quality. The study assessed the ecological effects of small-scale irrigation farming along the WVR in the Bawku West District of Ghana. A cross-sectional, quantitative approach was used, with structured questionnaires given to farmers in five communities along the river. Participants were purposively selected based on the proximity of their farms to the river and how often they farmed throughout the year. Data analysis was performed using SPSS 20.0 and STATA 14.0. Results showed the main crops grown, including onions (40%), okra (20%), pepper (13%), leafy vegetables (9%), and fruit crops like watermelon (18%). Common land preparation methods included weeding with a hoe, chemical spraying, burning, creating sunken beds, and building ridges and earth bunds. Farmers mostly relied on self-managed flood irrigation systems. Environmental impacts identified included vegetation destruction and stunting, land degradation, gully erosion, siltation of riverbeds, and weed overgrowth. These issues are worsened by the area's dry conditions and the practice of continuous dry-season farming. The findings suggest that the WVR is under significant pressure due to increased irrigation activities. The study recommends reintroducing intensive extension services and targeted awareness programs to encourage environmentally sustainable farming practices among dry-season farmers.

Keywords: Environmental Impact, Dry Season Farming, Small-Scale Irrigation, White Volta Basin, Bawku District

Introduction

Most regions of Africa depend on rainfall for crop production, which poses significant challenges to sustainable agriculture, food security, and farmers' livelihoods (Olarewaju et al., 2025; Adenle et al., 2016; Oruonye, 2011; Nhamo et al., 2016). Climate change worsens these issues and is likely to have long-lasting impacts on food production. Several studies indicate that climate change significantly disrupts rainfall patterns, even during the rainy season, leading to uneven distribution and dry spells that decrease crop yields (Oruonye, 2011; Adenle et al., 2016; Fontaine et al., 2018) and result in water shortages, which remain one of the biggest barriers to agricultural sustainability in Africa. As Ziba (2015) points out, limited water availability is a major obstacle to crop production, especially since yields are closely linked to water availability during critical growth stages (Eziakor, 1988). Whether under rain-fed or irrigated conditions, crops require sufficient moisture for optimal growth, and agriculture accounts for the largest share of global freshwater use, highlighting the sector's heavy reliance on water resources. It is estimated that water use in the agriculture sector worldwide increased by 70% from the 1940s to 2000 (Wheeler et al., 2015). Therefore, effective irrigation is essential for boosting agricultural productivity and ensuring national food security, as emphasized by Owusu et al., (2017).

Given the growing unreliability of rainfall, access to irrigation water has become essential for reducing the negative impacts of climate change and ensuring food security in many parts of Africa (Oruonye, 2011). In Ghana, irrigation is typically practiced during the dry season. Donkoh et al. (2016) noted that dry season farming not only boosts yields during the main rainy season but also supports year-round food availability, employment, and overall growth in the agricultural sector. It has also been shown to raise income levels and improve living standards for rural farmers.

Provision of irrigation is widely recognized as essential for reducing poverty, increasing household incomes, and supporting the broader economy (Adam et al., 2016). Different authors have provided various definitions of irrigation. Unami et al. (2013) define it as the application of water from a supply source onto a farm to meet crop moisture requirements. Ziba (2015) describes it as the practical release of water onto farms to supply moisture for crops. Oladimeji and Abdulsalam (2014) argue that irrigation is the technical practice of artificially supplying water for agricultural activities when rainfall is scarce or absent. Others categorize irrigation as a system that provides water artificially to plants in dry regions for use during the dry season (Hillel and Vlek, 2005). All these definitions agree that irrigation increases water availability to crops, especially during dry periods, thereby helping to sustain yields.

Small-Scale Irrigation Farming

The term "small-scale irrigation farming" refers to cultivating crops on relatively small plots, where farmers have full control over water management (Akenten, 2013). Although many studies emphasize the importance of large-scale dry-season irrigation farming (Oladimeji and Abdulsalam, 2014; Donkoh et al., 2016; Adam et al., 2016), the localized and context-specific nature of small-scale irrigation practices makes them particularly significant. Farmers' practices vary depending on factors such as educational level, income, available technology, and water application methods, as noted by Al-qinna and Salahat (2017). These differences are further influenced by each farmer's level of irrigation expertise, which has important implications for environmental sustainability. In these systems, farmers independently manage and make operational decisions about drainage setup, field boundaries, canal layout, outlets, and water distribution systems (Onuk et al., 2017; Usman, 2015). In this study, small-scale irrigation explicitly refers to the manual haulage of water from rivers for dry-season crop production.

The unimodal rainfall system in Northern Ghana is characterized by distinct wet and dry seasons (Balana et al., 2019b). Dittoh et al. (2013) reported that although the dry season typically lasts from November to May (seven to eight months), the wet season lasts only four to five months. This extended dry period is associated with poverty in the region, where agriculture is the primary source of livelihood. As a result, dry-season farming has emerged as a crucial strategy for reducing poverty, increasing food availability, and promoting employment (Dittoh et al., 2013; Fontaine et al., 2018). According to Oruonye (2011), small-scale irrigation during the dry season is a worthwhile investment that supports farmers' livelihoods. Communities near water bodies often adopt dry-season irrigation to ensure household food security and sustain incomes (Alare et al., 2018). This practice has become widespread in response to unreliable rainfall patterns. Farming practices associated with this system, such as land preparation, irrigation, fertilizer application, weeding, pest management, and harvesting, play vital roles in crop production. However, depending on how they are managed, these practices can either support or harm the environment (Önder et al., 2011).

Impacts of Small-Scale Dry-Season Irrigation Farming Practices

Agricultural activities in most areas depend on rain-fed conditions; however, due to climate change, rainfall has become increasingly unreliable for crop production. As a result, wet-season farming has become constrained by climatic factors, necessitating dry-season farming as a supplementary alternative to ensure food security (FAO, 2014; Nyamba & Zidouemba, 2025). Dry-season farming offers clear benefits but also presents challenges. Research indicates that dry-season farming is a cost-effective approach for farmers, offering employment and stable revenue (Onuk et al., 2017; Mustapha et al., 2016; Oladimeji and Abdulsalam, 2014). However, difficulties persist, including limited land availability and high evapotranspiration under unfavorable climatic conditions, leading to water stress during the peak of the dry season. A reliable water source for irrigation is therefore essential. Farming along available water bodies thus becomes highly desirable. However, farming in river catchments can lead to environmental impacts, including riverbank erosion, siltation, degradation of soil and water quality, and vegetation loss (Singh, 2015; Mango et al., 2018; Asfaw Eshetu & Mekonen, 2024; Daru & Alemu, 2024). Practices such as slash-and-burn, excessive pesticide use, heavy tillage, and improper equipment handling disrupt soil structure, reduce microbial populations, and increase erosion and compaction (Kimmage & Adams, 1990; Wilson & Tisdell, 2001; Wandaat & Kugbe, 2015). In addition, the heavy application of fertilizers – often necessary to maintain yields – can degrade soil fertility over time (Pimentel, 2005), resulting in a cycle of increased chemical use.

When precipitation is favorable, the wet season is usually rich in food, and prices are low, which reduces farmers' economic returns. In contrast, dry-season farming provides higher profits, encouraging farmers to intensify production to maximize gains (Stuart et al., 2017). However, without sustainable practices, the long-term environmental impacts of dry-season farming can be extensive.

Indigenous farmers along the White Volta are well aware of the benefits of irrigation farming, particularly in terms of food, income, and employment. As a result, they are inclined to adopt any available methods to improve yields. However, environmental sustainability is often compromised for economic gains. The underlying concern, therefore, is how to increase food production while protecting the environment.

Since farmers prioritize food production and income above all else, they often go to great lengths, including the inappropriate and dangerous formulation of their own chemical mixtures, which they believe are effective for production. While such practices may boost crop yields in the short term, they significantly contribute to the degradation of topsoil and water quality (Onuk et al., 2017; William et al., 2015; Nonga et al., 2011).

Although the dry season is a period of irrigation farming that provides economic benefits, it poses environmental risks when not managed sustainably. The study, therefore, builds on the concept that while small-scale dry-season farming is beneficial, it is also increasingly subject to unsustainable practices that degrade environmental resources.

This study contributes to the broader discussion about agriculture's ability to adapt to climate change by showing how small-scale irrigation practices, though vital for rural livelihoods, can unintentionally degrade ecological systems. It aligns with sustainable land management frameworks that emphasize balancing productivity with environmental integrity, particularly in climate-sensitive regions such as Northern Ghana.

Research gap

Studies have examined dry-season farming, small-scale irrigation strategies, and climate-smart agricultural practices in the north. However, very few have empirically assessed the potential of small-scale dry-season farming to contribute significantly to environmental degradation through its methods. Similarly, there is a dearth of information on how water-stress management strategies and economic considerations have influenced the selection of specific crops for cultivation during the dry season. This study, therefore, examines the environmental impacts of small-scale irrigation farming along the White Volta

River, focusing on irrigation methods, cultural farming practices, and strategies for managing water stress and crop selection.

Materials and Methods

Study area

This research was conducted in the Bawku West District of the Upper East Region, Ghana (Fig. 1). It lies between latitudes 10°30 and 11°10’N and longitudes 0°20 and 0°35’E. It shares borders with Burkina Faso to the north, East Mamprusi District to the south, Bawku and Garu Municipals to the east, and Talensi and Nabdam Districts to the west (Adu Kyere et al., 2013; Asamoah & Ansah-Mensah, 2020). The vegetation is predominantly savanna, featuring drought-resistant deciduous trees and widespread shrubs. The area is characterized by open grassland that is sparse or bare and prone to erosion (Population & Housing Census, District Analytical Report, and BWD Dept. of Agri profile, 2010).

The rainfall regime is unimodal, spanning June to September, with a dry season of 6 to 8 months (October to April) (Balana et al., 2019). The average rainfall in the region is 956 mm, and the average temperature and humidity are 34°C and 56%, respectively. Soil fertility is low in most parts of northern Ghana. The average organic matter content is less than one percent due to prolonged soil leaching, which generally limits soil fertility. The district's residents are primarily small-scale farmers, with 90% of their farmland less than 2 hectares. Because the area experiences a unimodal rainfall pattern, people typically engage in dry-season vegetable farming on small plots along riversides to access irrigation water, and the farming is heavily dependent on agrochemicals to improve yields.

Figure 1 Bawku West District Map Depicting Farming Communities along the WVR

Data Collection and Analysis

A quantitative approach was used to examine the environmental impacts of dry-season irrigation farming. The total population of farmers in these communities was 4,544 and the sample size was determined by the Yamane formula (1967):

$$n = \frac{N}{1 + Ne^2}$$

n = Sample size
N = Total Population of farmers (4,544)
e = Degree of error expected (0.05)

The above expression gave a sample size of 400. Even though the calculated sample size was 400, 410 questionnaires were administered to account for lost and non-responders. At the end, a total of 403 answered questionnaires were retrieved, as indicated in Table 1.

The questionnaires were semi-structured and

TABLE 1
Sampled Communities

Community	Population	Workout	Sample size
Karinatinga	587	587/4544*405	52
Timonde	429	429/4544*405	38
Yarigu	2076	2076/4544*405	184
Kobore	1054	1054/4544*405	94
Zongoire	396	396/4544*405	35
Total	4542		403

purposively administered to farmers in five selected communities proximate to the White Volta River. Within each community, farmers were randomly sampled, and every third farmer was selected for an interview. This purposive selection ensured that respondents were engaged in dry season farming near the White Volta River and therefore had the requisite knowledge to provide relevant and reliable insights. According to Etikan et al. (2016), purposive sampling is appropriate when participants are well informed and able to articulate their views on the research topic. The selected respondents represented communities (Table 1) from the northern, middle, and southern stretches of the White Volta River. The overall sample size was sufficiently broad to generate meaningful data for the study and to meet the requirement for adequate representation (Hossan et al., 2023).
Primary and secondary data were collected: primary data from questionnaires and secondary data from government agencies, such as the Ministry of Food and Agriculture (MOFA) and the District Assemblies. Additionally, in-depth one-on-one interviews were conducted with key informants to elicit views on dry-season farming methods and their effects on environmental resources, and to gain insight into changes observed in farmlands, the riverine system, crop growth, and yield over the years.
The software used to process the data collected was Statistical Package for Social Sciences (SPSS) version 20.0 and Microsoft Excel (2010). Descriptive statistics were used. A 5-point Likert scale, ranging from "strongly disagree" (1) to "strongly agree" (5), was used to analyse the questionnaires. A multiple logit regression model in Stata 14.0 was employed to analyse the factors influencing a farmer's decision to cultivate a crop. The logistic model is as follows:

$$Logit(Y) = In\left\{\frac{Pi}{[1-Pi]}\right\} = \beta0 + \beta1X1 + \cdots + \beta iXi + \varepsilon i \quad (1)$$

Where:
Y is the dependent variable and represents any crop that may be considered for cultivation; P is the probability of a farmer choosing *Y* or otherwise. The β_0 is the intercept, $\beta_1, \beta_2 \ldots, \beta_i$, are the constants of the independent variables, $X_1, X_2 \ldots, X_i$. These independent variables are experience, age, gender, education, marital status, household size, distance from a water body, land size, quantity of fertilizer, group membership, access to extension services, and other relevant variables (as defined below). εi is the error term (Canavari & Rivaroli, 2007).

Crops:
0 = leafy
1 = Onion vegetables
2 = Watermelon
3 = Okra

The independent variables were:
X_1= Age (years)
X_2= Gender (Male ref. female)
X_3= Marital (single = 1; married = 2; widowed = 3; divorced/separated = 4)
X_4= Household size (number)
X_5= Education (years)
X_6= Experience (years of dry season farming)
X_7= Farm size (acres)

X_8= Quantity of fertilizer (Kilogram)
X_9= Group membership
X_{10}= Extension service

Results and Discussion

Demographics of the Study Area

Table 2 presents the respondents' demographic characteristics. The respondents are predominantly male (about 93%), and most were aged 44-56 years, with a mean age of 49. This aligns with findings from similar studies (Ojo et al., 2009; Ayodele et al., 2016). Only a small proportion of respondents were youth aged 18-30, indicating low youth participation in dry season farming. More than half lacked formal education. Ninety-nine percent of the respondents were identified as small-scale irrigation farmers (Fig. 2). Several factors may explain this trend, including limited access to capital, lack of interest, or pursuit of alternative opportunities in urban areas such as Kumasi or Accra. Yong (2014) and Acheampong (2015) both noted that individuals under 40 are generally less inclined to pursue farming as a livelihood, often migrating in search of better economic prospects.

In terms of educational attainment, over half (52.4%) of the respondents had no formal education, while 25.3% had completed secondary education. Only 0.2% had a tertiary education. Most respondents had 1-10 years of experience in dry season farming, representing 71.2% of the sample. Only 0.9, 5.3 and 23% had dry season farming experience between 31-40, 21-30 and 11-20 years, respectively.

Nearly all respondents (99.5%) also engaged in wet-season farming, with only 0.5% indicating they did not—most of whom were migrants engaged in dry-season farming as a business investment. Although farming remains a primary occupation in the area, it is often regarded as a fallback when other forms of employment fail. One respondent (1.1%) pursued alternative jobs, such as trading, masonry, carpentry, and artisanal work, as shown in Fig. 2. Interestingly, some individuals who initially migrated for work eventually returned to farming. Many of these returnees had limited interaction with agricultural extension officers, as agents

TABLE 2
Distribution of Demographic Characteristics of Respondents in the Study

Variable Estimated	Frequency	Percent	Mean
Gender of the Respondent			
Male	375	93.05	
Female	28	6.9	
Total	403	100	
Age Distribution			
18-30	41	10.2	
31-43	144	35.7	
44-56	198	49.1	49
57-69	18	4.5	
70-82	2	0.5	
Total	403	100	
Educational level			
No formal education	211	52.4	
Primary/basic	44	10.9	
Middle/JHS	45	11.2	
Secondary/SHS	102	25.3	
Tertiary	1	0.2	
Total	403	100	

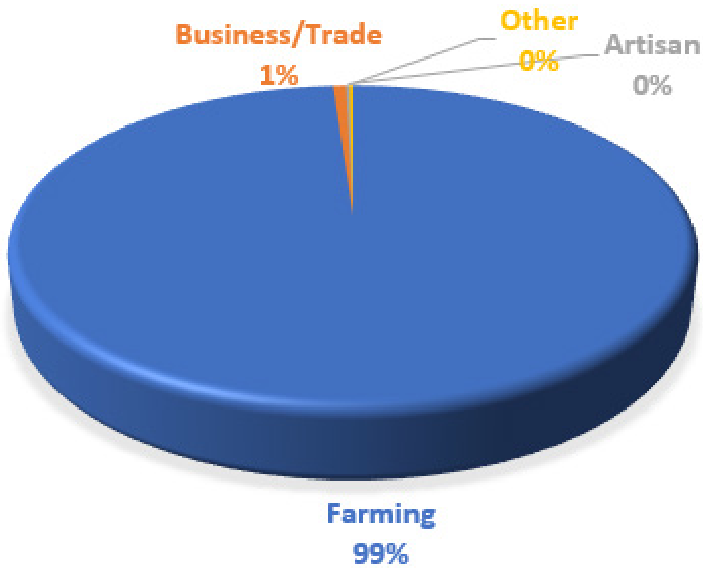

Figure 2 Occupation of Respondents in the Study

usually maintain long-term relationships with permanent residents. Approximately 90.8% of farmers reported not having joined any organized group, whereas 9.2% belonged to groups, many of which were inactive or no longer functioning. As a result, these farmers were less likely to access extension services. Of those who had received some form of extension support, only 12% were assisted by MoFA, with the remaining 40% receiving support from NGOs or development partners. However, most of this support was not specific to dry-season farming and irrigation or to their impacts on environmental sustainability.

The study also revealed that farmers operating on larger land sizes – typically 15-20 acres or more – accounted for only 6% of respondents (Fig. 3) and were more likely to receive expert advice than the dominant small-scale farmers. The vast majority (94.7%) were smallholders managing 0.5 to 5 acres (Fig. 3), consistent with findings by Adam et al. (2016) and Balana et al. (2019). Most of these farmers cultivated less than 3 acres during the dry season and more land during the wet season, as shown in Fig. 3. This pattern often occurs because land closer to the WVR is limited and not always privately owned. In contrast, farmers tend to cultivate land near their homes during the wet season.

Mono-cropping and flood irrigation are widely practiced in the area. The dominant irrigation

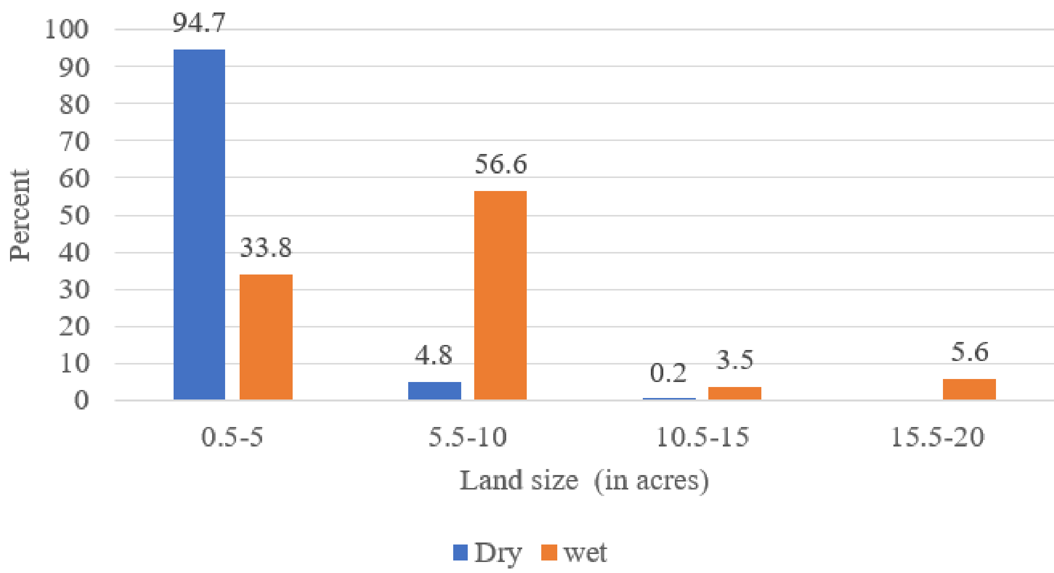

Figure 3 Size of land cultivated in the dry and wet seasons

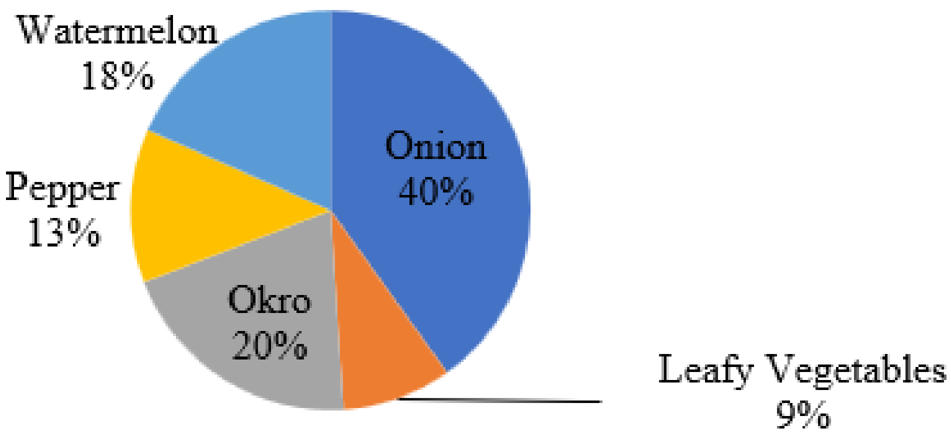

Figure 4 Proportion of major Dry Season crops cultivated

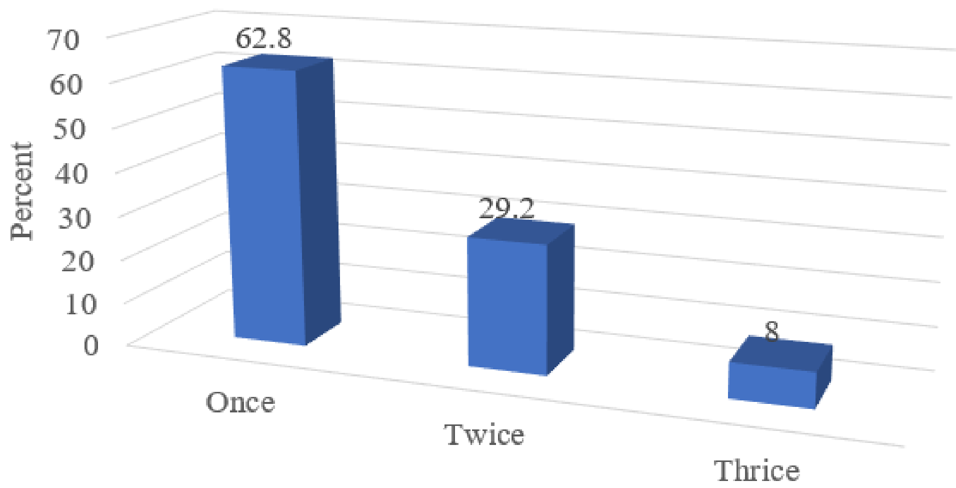

Figure 5 Frequency of Cultivation in a year

technology in the study is fuel-powered or small motorized pumps, which are operated predominantly by men (Namara et al., 2013). The main irrigated crops grown in the dry season include onion (40%), okra (20%), watermelon (18%), pepper (13%), and leafy vegetables (9%), as shown in Fig. 4. A small percentage (14%) engage in mixed cropping, usually combining a primary crop with various leafy vegetables (Fig. 4). It was observed that farmers often develop and adopt innovative practices based on their experiences and also on trial-and-error basis.

Irrigation farming in the area is highly intensive. About 29.2% of farmers cultivated the same land twice within the season, while 8% farmed three times on the same plot, as shown in Fig. 5 below. This level of intensity was made possible for those who could afford the necessary inputs. The dominance of vegetable cultivation demands significant attention and investment. As a result, farmers are highly committed to maximizing yield, even though this investment has substantial implications for the WVR and surrounding ecosystems. In the absence of regular extension services, farmers relied on experience, peer learning, and self-developed strategies. This includes experimenting with cocktail mixtures of chemicals to enhance yields and manage pests or weeds. While such innovations may offer short-term benefits, they pose long-term risks to the sustainability of the WVR and its surrounding areas.

Factors influencing crop selection for cultivation

The results of the logistic regression analysis of farmers' crop selection are presented in Table 3. The reference crop is onion, as it is the most widely cultivated among farmers. The determinants of a farmer's crop selection for production include marital status, age, education, gender, land size, distance to a water source, household size, experience, fertilizer quantity, group membership, and extension support. Farmers have various reasons that affect their decisions about which crops to produce. Whereas a woman may prioritize leafy vegetables to meet household needs, a man may choose crops based on market value to ensure financial security (Dittoh et al., 2013), and in this study, onion was the choice of most men. Few women are involved in onion production because it's cultivation is more labor-intensive and this aligns with a study by Sidibé et al. (2016). Because the yield potential of crop varieties and market demand shape crop selection, farmers' knowledge of market dynamics influences their choices. In this case, they are more likely to cultivate onions than leafy vegetables, even though onion production is more labor-intensive. Ajewole and Folayan (2008), as cited in Adeoye et al. (2011), noted that understanding differences in farm resources and productivity enhances effectiveness. In other words, informed farmers are more likely to adopt practices and cultivate crops that bring higher income. Farmers' preference for onion production stems from the fact that onions can be preserved for longer periods, until prices improve, unlike leafy vegetables, which are highly perishable. Thus, large-scale cultivation of leafy vegetables is associated with a higher risk of low economic returns (Dittoh et al., 2013). In the same vein, older farmers were more likely to cultivate watermelon than onions, possibly because watermelon production is less demanding in terms of inputs, labor, and time. Although watermelon is input-demanding (Adeoye et al., 2011), it is not as labor-intensive as onion farming. Nevertheless, factors influencing farmers' choices include age, labor availability, and fertilizer use.

The significant negative coefficient for education in relation to leafy vegetable cultivation suggests that more educated farmers preferred market-driven crops such as onions or watermelon. This supports the idea that knowledge shifts priorities. Similarly,

TABLE 3

Regression Analysis on Crop Selection by Farmers

	LEAFY	**OKRO**	**MELON**
VARIABLES	**COEFFICIENT**	**COEFFICIENT**	**COEFFICIENT**
Marital status	-1.725**	0.507	-0.357
Gender	-3.840***	-1.018	-0.572
Education	-1.099**	-0.329	0.0863
Age	0.00925	0.0115	0.0369*
Quantity of fertilizer	-0.0048	0.00107	0.00567**
Extension services	-0.67	-0.252	0.883**
Group membership	-0.116	0.152	-1.802*
Farming experience	0.0494	-0.0471*	-0.138***
	-0.0312	-0.0247	-0.0373
Constant	3.353**	-0.397	-1.987
	-1.55	-1.251	-1.609
Observations	398	398	398

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

extension services positively influenced the decision to grow watermelon, suggesting that advisory services tend to promote diversified cropping systems, likely due to improved water management or input guidance. The regression provides practical insights into how demographic and institutional factors shape cropping decisions, reinforcing the importance of tailored extension strategies and farmer support.

Agronomic and cultural practices engaged by farmers along the White Volta basin

The natural components of the environment – soil, water, and vegetation – are interconnected in complex ways, and when one component is impacted, others are invariably affected. Many key factors that degrade the environment are human-induced, such as agricultural activities and deforestation. Anthropogenic influence is therefore a determinant of ecosystem integrity. Ampadu et al. (2017) observed that agriculture contributes significantly to social welfare; however, when intensified, it can lead to soil erosion, loss of fertility, and vegetation degradation.

Typical land preparation methods included manual weeding with hoes and cutlasses, chemical spraying, and slash-and-burn (Table 4). The cleared land is prepared by constructing ridges, raising beds, applying fertilizers, and designing irrigation canals. Hager (1994) describes manual weeding as the physical removal or disturbance of weeds by hand or with a hoe. Compared with chemical weeding, manual methods are more labor-intensive (Jabran et al., 2012). Chemical weeding, though fast and less labor-intensive, can adversely affect soil microbes, depending on the chemical used (Hager, 1994). Manual tillage, on the other hand, is a major factor in degrading soil texture and structure and in reducing moisture content (Ampadu, 2017). When tillage occurs near the river course and is frequent, it affects river hydrology.

Farming practices in communities along the WVR were similar (Table 5). The survey showed that monocropping is predominantly practiced during the dry season, and that almost all farmers did not use mulching as a moisture-conservation method (Table 5). Mulching was only done during the seedling nursery stage, often on a separate plot, before transplanting.

Practices such as the regular burning of farm residues, cutting of shrubs for use as

TABLE 4

Forms of Land Preparation by the Respondents

Activities	Percent
Weeding Manually (Hoeing)	
No	12.2
Yes	87.8
Total	100
Weedicide Application	
No	17.5
Yes	82.5
Total	100
No/Minimal Tillage	
No	83
Yes	17
Total	100
Creating Ridges	
No	0
Yes	100.0
Total	100

TABLE 5
Farm Management Practices

Activities	Percent
Mixed cropping	
No	86
Yes	14
Total	100
Crop rotation	
No	96.5
Yes	3.5
Total	100
Mulching	
No	98.3
Yes	1.7
Total	100

fuelwoods and animal feed, as well as for the construction of huts may significantly reduce the organic matter content of soil in the study area. Additionally, the scarcity of vegetative cover during the dry season exposes the soil to wind and water erosion, and this could also contribute to reducing soil fertility. The sustainability of crop production and yields depends on effective soil management practices. Key interventions include erosion control and the increase of organic matter through composting or farmyard manure. These methods help replenish nutrients lost through erosion, leaching, and plant uptake. Fortunately, the WVR contributes natural replenishment by depositing fertile alluvial soils along the riverbanks during seasonal floods.

The widespread use of agrochemicals, pesticides, and fertilizers for crop protection and yield improvement was evident across the study area. Approximately 93% of farmers practiced exclusively inorganic farming. Yong (2014) conducted a study in the Bawku West District and found that, despite efforts to promote compost use, only one farmer in the community adopted it. Farmers reported that compost production is labor-intensive and time-consuming, making it less attractive than chemical inputs. While farmers acknowledged that chemicals are costly, they also found them more convenient. Many expressed willingness to use compost only alongside chemicals, but not as a substitute – particularly in the dry season. This opinion is justified by the believe that seasonal floods from the WVR contribute sufficient organic matter to support crop growth during this period. However, in the dry season, inorganic fertilizers are preferred. The most frequently used agrochemicals include: chemico (NPK), NPK active (Yara), AMG compounds, including urea and adwumawura, and AMG-Sulphate. Pesticides used included: Confidor, agoo/powder, tricel, K-optimal, and Dursban. Weedicides included glyphosate (Roundup), atrazine, and landlord. These agrochemicals fall under various chemical classifications – organochlorines, organophosphates, and pyrethroids –all of which have long-term residual effects in the soil and on water quality, especially when adsorbed onto soil particles.

Coping Strategies in Dry Season Small-scale Irrigation Farming

The primary source of irrigation water in the Bawku-West District is the White Volta River, which is dammed upstream (Bagre dam, Burkina Faso). Other sources include dugouts and pipes (3%). However, the majority of farmers (97%) reported that, apart from the White Volta, no other water sources were available. Many (86.5%) also believe the river does not completely dry up, while 13.5% believe it does. These views depend on the farmer's location along the river course –

upstream, midstream, or downstream. While some parts dry up completely, others retain water as isolated pools and puddles in the riverbed during the peak of the dry season. This fact was also substantiated by the Bawku West District Assembly (BWDA, 2006), a report by Yong (2014), and Agyare et al. (2008).

The study found that the Bagre Dam in Burkina Faso plays a significant role in water supply during the dry season. The dam is opened about once a week on average. This regular release of water ensures a steady flow in the riverbed, as also noted by Amuguandor (2016). When there are delays in the dam's schedule, farmers turn to using irrigation pipes to draw water from distant pools to their farms. When these pools are too far to reach easily, farmers dig shallow wells within the riverbed to access shallow groundwater. Although these practices are effective coping strategies, they only work as long as the dry spell is short. Nonetheless, farmers generally agree that their water shortage is not as severe as one might think. They usually manage to irrigate their fields throughout the dry season.

Environmental Impacts

Various activities in the area have been linked to numerous environmental effects, especially those related to irrigation farming (Amerasinghe and Boelee, 2004). Evidence of gallery forest destruction confirms the increasing use of the river for cultivation. Although the area is part of the savannah zone, the natural vegetation along the riverbanks (gallery forest) has been gradually cleared to facilitate irrigation. Figure 6 shows land being cleared closer to the river each dry season, with the impact of soil tilling. During the wet season, lands near the river are usually flooded, making cultivation in these areas unreliable. Farmers therefore mainly cultivate in savannah forest zones during the wet season and return to the river areas during the dry season. This shifting is believed to contribute to scouring/erosion of the river walls (Fig. 8), riverbed siltation (Fig. 10), and reduced vegetation.

Additionally, the frequent dragging of irrigation pipes across the riverbank contributes to soil loosening and gulley erosion. This activity may also be contributing to siltation of the riverbed. Onder et al. (2011) confirm that improper tilling leads to soil erosion. As the already poor soils lose organic matter, they become more susceptible to wind and water erosion, with sediments washing into the WVR.

Another notable challenge observed was the proliferation of resistant weeds due to chemical use (Fig. 9). These weeds have vigorous growth rates, are persistent and compete with cultivated crops for nutrients. While these chemicals initially boost yields and yield returns (Damalas, 2009), they degrade soil health over the long term. Baishya (2015) explains that chemical inputs degrade soil quality by depleting nutrients, destroying organic matter, and increasing compaction and erosion. Despite these environmental consequences, many farmers continue using agrochemicals for immediate gains. About 57% of farmers (Table 6) confirmed that irrigation water from farms often flows

TABLE 6

Environmental Consequences of the practice of irrigation

Effects of irrigation activities	Agree (%)	Disagree (%)	Not sure (%)
Increasing dependence on fertilizer	88	10	2
Stunted vegetation along river riverbank	53	24	23
Water flow back into river during the irrigation	57	30	13
Development of gully erosion along riverbank	68	28	4
Gully erosion intensifies	72	20	8
Destruction of vegetation along riverbank	85	10	5
Farming activities along the river have increased siltation in the riverbed	20	54	26

Figure 6 Farm close to the WVR

Figure 7 Fuel engine pump almost in the River (suggesting possible contamination of water with oil)

Figure 8 Scouring of the WVR resulting in gully formation

Figure 9 Display of resistant weeds among cultivated onions

Figure 10 Siltation of Riverbed

back into the river, suggesting possible agrochemical contamination, along with fuel residues from engine pumps (Fig. 7).

Studies suggest that flood-prone areas tend to have rising water tables (Magdoff & Van, 2007; SARE, 2012). This helps explain the frequent flooding of land near the river. The use of flood irrigation near rivers also contributes to soil salinization and raises groundwater levels through capillary action (SARE, 2012), especially in arid zones.

The intensive nature of irrigation farming, combined with limited regulatory oversight, has led to self-managed practices that may be ecologically unsound. The fact that most farmers reported no significant water stress despite clear signs of riverbed drying suggests an adaptation threshold that could soon be exceeded if upstream water releases decline or climate variability worsens. Additionally, farmers' reliance on personal innovation (e.g., chemical mixtures) in the absence of extension support reflects a system driven more by necessity than informed planning. This creates tension between immediate livelihood gains and ecological sustainability – a tension that policy must urgently address.

Figure 11 shows a typical irrigation method used by smallholder dry-season farmers in the study area. Water is drawn from the river (inlet) using a motorized pump and channeled through a main conduit, which then distributes it via canals or gutters to individual plots. Bunds or ridges control the flow and retention

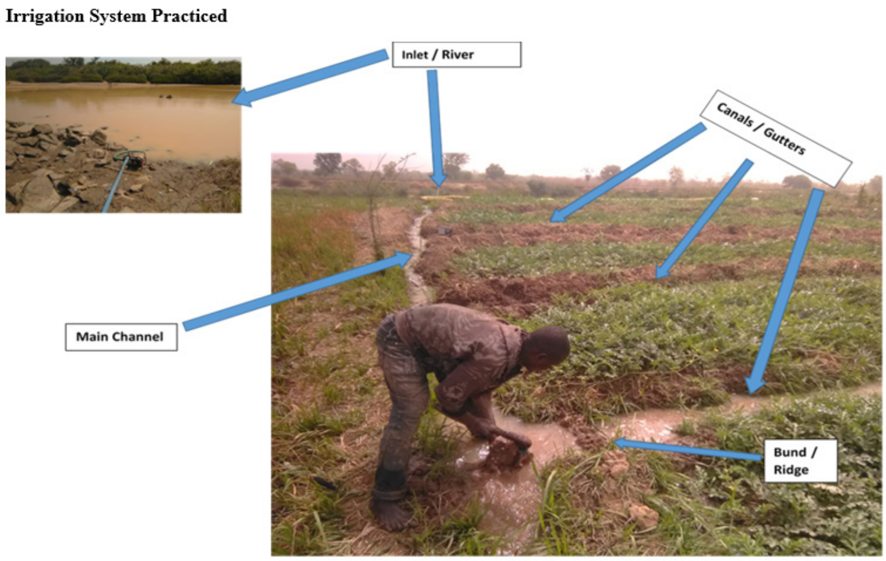

Figure 11 Schematic illustration of flood irrigation system Practiced Along the White Volta River

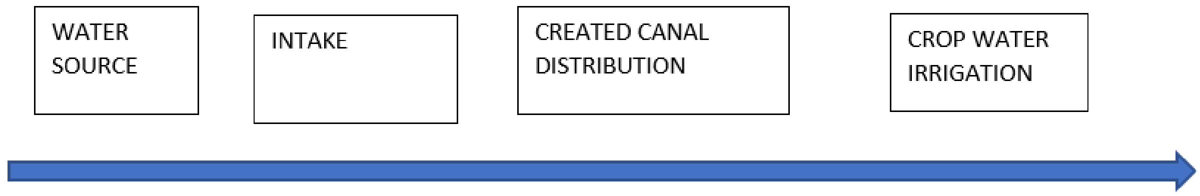

Figure 12 Water supply scheme pertaining to the study area

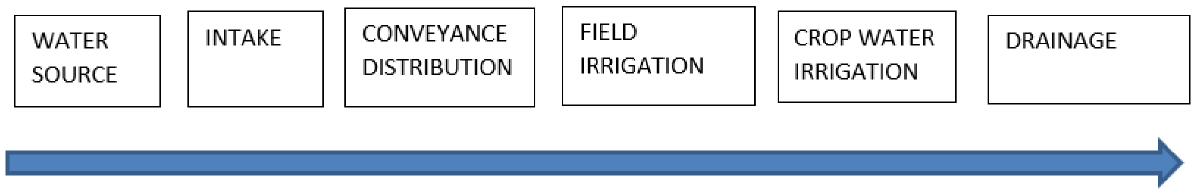

Figure 13 Generalized illustration of water supply scheme by Smith et al., (2014)

of water between the plots. This system is popular because it is affordable and suitable for small-scale operations. It is also preferred over flood irrigation, which can cause significant topsoil erosion, nutrient loss through washing, and damage to riverbanks due to uncontrolled water flow.

A diagrammatic representation of the irrigation operation is shown in Fig. 12, depicting how water flows from the water source to the field. For comparison, Fig. 13 presents a more generalized irrigation system described by Smith et al., (2014), where water is drawn from the source and distributed through a structured drainage system.

Conclusion and Recommendation

The study assessed the environmental impact of small-scale irrigation farming along the White Volta River (WVR) in the Upper East Region (UER). The findings indicate that irrigation is a key component of agricultural production in Northern Ghana, significantly contributing to food security and farmers' economic growth. However, these benefits come with serious environmental costs. Farmers are primarily motivated by the need to sustain production and make a profit, often overlooking the environmental implications of their practices. The study found that dry-season farming contributes to land degradation, gully formation from irrigation pipes rubbing against the basin walls, erosion from irrigation trenches, and siltation of the riverbed, along with the transfer of agrochemicals into the WVR. Weed proliferation and low soil fertility are further exacerbated by increased pesticide use. Although the river's flow diminishes significantly during the dry season, occasionally reducing to disconnected pools, farmers adapt by extending irrigation pipes or dredging the riverbed, which introduces additional environmental stress.

Based on the research findings and conclusions, the following recommendations are proposed:

The Ministry of Food and Agriculture (MoFA), in collaboration with the Ghana Irrigation Development Authority (GIDA), should promote sustainable farming by discouraging harmful land preparation methods, such as slash-and-burn and excessive tillage, and by supporting smallholder farmers through training in good agricultural practices (GAP), including soil fertility management, sustainable cropping systems, and integrated pest management.

GIDA should develop and promote simple, affordable, and environmentally friendly irrigation technologies while collaborating with local authorities to conduct regular environmental education campaigns that raise awareness of the impact of poor irrigation practices on riverbanks, soil structure, and water bodies.

Policymakers should support the development of small-scale water harvesting and storage systems – such as lined canals, shallow wells, and mini-reservoirs – and ensure that agricultural extension agents (AEAs) are resourced to guide farmers in climate-smart irrigation scheduling techniques.

Future studies should examine the relationships among methods, crop productivity, and soil and hydrological conditions in the White Volta basin, with findings integrated into regional water and land use policies to promote sustainable agriculture and environmental conservation.

Limitations and Areas for Future Research

The study offers valuable insights into the environmental impacts of small-scale irrigation farming along the White Volta River. However, a few limitations are worth noting. First, the study relied primarily on farmers' responses, which may be subject to bias or exaggeration. Second, while the study identified key environmental consequences, it did not conduct laboratory tests on soil or water samples to quantify pollution levels or sedimentation. Additionally, the study focused on a specific stretch of the river, and the findings may not generalize to the river basin or ecological zones. Future research could incorporate soil and water quality assessments to validate environmental degradation indicators. Further studies may also explore gendered access to irrigation, the role of informal knowledge systems, and long-term economic trade-offs between short-term gains and ecological sustainability.

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Credit author statement

A. A. A: Conceptualization, Data collection, Methodology, Writing of draft manuscript.
S. S. K: Conceptualization, Data analysis, Review and editing of draft manuscript.
B. Y. F-M: Reviewing and Editing of the draft manuscript.

Declaration of competing interest

The authors declare that they have no known competing interests or personal relationships that could have appeared to influence the work reported in this paper.

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