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Adoption of Climate Smart Agricultural Technologies among Smallholder Farmers in Semi-Arid Ghana

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Abstract

The evidence of climate change and variability in semi-arid Ghana is glaring and the adverse impact is being felt mostly by smallholder farmers because of their over dependence on agriculture for livelihood and subsistence. As a solution to building the resilience of the smallholder farmers, the Climate Smart Agriculture (CSA) concept was introduced a decade ago by the Food and Agriculture Organization, guided by three key principles of adaptation to climate change, greenhouse gas emissions reduction and promotion of food security. The paper sought to assess the level of awareness of climate smart agriculture practices and the respective rate of adoption of these practices. Moreso, this paper established how Normalised Difference Water Index (NDWI) and Land Surface Temperature (LST) affects the adoption rate of CSA practices or technologies. The study employed the explanatory sequential mixed research methods. A semi-structured questionnaire was used to collect data from 300 smallholder farmers and 16 focus group discussions were conducted, with a total of 180 persons taking part in the focus group discussions. Key informant interviews were also conducted for 11 relevant stakeholders from governmental and non-governmental institutions. Findings from this study reveal that CSA practices such as intercropping, manure management and mulching had a 100% adoption rate, and the least adopted practice was irrigation followed by dry season gardening. The NDWI and LST analysis concluded that Nandom is the most viable among the two municipals to support irrigation projects since it has more capacity to retain surface water during the dry and wet seasons.

Keywords: adoption rate, awareness level, Climate change, climate smart agricultural technologies, smallholder farmers

1. Introduction

Agriculture is at the nexus of three of the greatest challenges of the 21st century, that is the attainment of food security, adaptation to climate change and variability, and mitigation of climate change (Beddington et al., 2012). On a global scale, climate change has significantly hit the agricultural sector posing a risk to farming systems and food security. As temperatures increase, pests and diseases find new ranges and rainfall patterns alter (Neate, 2013; Vermeulen et al., 2012; Costello et al., 2009; IAASTD 2009). The impacts of climate change, according to global climate circulation model shows that Sub-Saharan Africa is part of the most affected regions, with an anticipated decrease in agricultural yield for major food crops at about 20%, and increased incidence of food insecurity and poverty predominantly in rural areas (Trisos, et al. 2022; Arslan et al.,2015; Cline, 2008). In developing countries, agriculture provides jobs for 65% of the population, accounts for 29% of the gross domestic product, and economic health is closely linked to the fortunes, or misfortunes, of farming communities (Pye-Smith, 2011).

The increased vulnerability of farmers to climate change, due to their weak adaptive and coping capacities, threatens livelihood strategies and also the entire food production systems (Etwire, 2020; Harvey et al., 2014; Thorton et al., 2014; IPCC, 2014; Challinor et al., 2007). Studies conducted in West Africa confirmed that between 71 to 95 % of farmers are aware of the impacts of climate change and were already experiencing these impacts.

These findings are consistent with the various scientific assertions of models and empirical evidence made by farmers (Partey et al., 2018; Limatol et al., 2016; Yéo et al., 2016; Koura et al., 2015). Some of the most relevant climate change impacts in developing countries will be felt by smallholder farmers due to increased vulnerability status and the semi-arid regions of these developing countries are mostly adversely impacted by this occurrence (Trisos et al., 2022; Etwire et al., 2013; Morton 2007). MoFA (2007), defined smallholder farmers as "farmers having a farm holding of not more than two hectares and constitute about 90% of farm holdings in Ghana".

Agriculture used to be the major contributor to the Ghanaian economy until it declined over the years (NDPC, 2014). Nonetheless, its contribution to the economy is still significant (Yiridomoh et al., 2021). The major attribute of the small-scale system is that 90 percent of agricultural holdings are less than 2 hectares in size and are produced under rain-fed conditions (Etwire et al., 2013; Chamberlin, 2008; Asuming-Brempong et al., 2004). Climate change has impacted agricultural dependent activities, and the extent of the impacts is directly related to the level of vulnerability or exposure of farmers to these impacts (Derbile et al., 2022). The arid and semi-arid areas of Ghana have predominantly mixed crop-livestock and rain-fed systems and are recognised as high-risk areas needing urgent and sustained research and development activities (Wossen and Berger, 2015). In response to the impacts of climate change on the agriculture sector, the climate smart agriculture (CSA) concept has been promoted as a viable, integrative and practical tool to addressing these interconnected issues of food security and climate change (Derbile et al., 2022).

FAO (2013) defines CSA as "an approach that helps to guide actions needed to transform and reorient agricultural systems to effectively support the development and ensure food security in a changing climate". The introduction and implementation of CSA is a promising solution, and the absence of CSA will imply a reduction in the resilience of agriculture and food systems as well as the promotion of food insecurity in vulnerable areas (Derbile et al., 2022; Lipper et al., 2014). At the local level, CSA has been perceived as a set of practices that have been assessed for local viability or suitability and primarily aimed at improving a farmer's capacity to adapt to climate change, increasing the potential of carbon sequestration and ultimately meeting or exceeding food security goals. At the regional and national level, CSA is most often considered a conceptual framework that examines the trade-offs between the three "pillars" of adaptation, mitigation, and food security (Peterson, 2014, Lipper et al., 2014). Studies conducted by Bawakyillenuo et al. (2014), and Asante et al., (2012), revealed the following: a low adoption rate of CSA practices or technologies by smallholder farmers in Ghana are weak socio-cultural governance, environmental, educational, and economic structures were identified as setbacks in the practice and adoption of CSA interventions. In order to reduce vulnerability and enhance the adaptive capacity of farmers, CSA should be designed to be location specific. Therefore, the objective of the study is to assess the awareness and the rate of adoption of CSA in Lawra and Nandom municipalities as an effort to build smallholder farmers' adaptive capacities to climate change. Specifically, the paper 1) assessed the level of awareness of CSA practices and their respective rate of adoption and 2) establish if NDWI and LST affect the adoption rate of CSA practices or technologies. In this study, adoption was defined as the use of at least one practice in the last farming season (Alare et al. 2018).

2. Methods

2.1 Study Area

The study was carried out in eight communities in the Lawra (Tabier, Mettoh-Yipaala, Konwob, Eremon- Bompari) and Nandom (Kogle, Nabugangn, Tankyara, Danko) of the Upper West region of Ghana located in the semi-arid zone. This region is home to thousands of people and highly vulnerable to climate-related risks. Climate change and variability are expected to make conditions in these areas more challenging. The Lawra municipality is in the north-western corner of the region and this municipality is estimated to occupy a land size of 1,051.2 square km which is about 5.7% of the region's entire land size of 18,476 square km. The municipality has a population density of about 89 square km. Lawra is bounded to the east by Lambussie district, the north by Nandom municipal, and to the west and south by the Republic of Burkina Faso (GSS, 2014a; Lawra District report, 2018). The Nandom municipality is located in the northwest corner of the Upper West Region of Ghana and occupies a total area of 567.6 square km and constitutes about 3.1% of the region's total land area. Nandom is bounded to the south and east by Lawra and Lambussie respectively and to the north and west by the Republic of Burkina Faso. Eighty-eight communities represent the municipal with 86% of the inhabitants living in rural areas and the population density is about 89 per square kilometre (GSS, 2014b). Figure 1 is the map of the study communities.

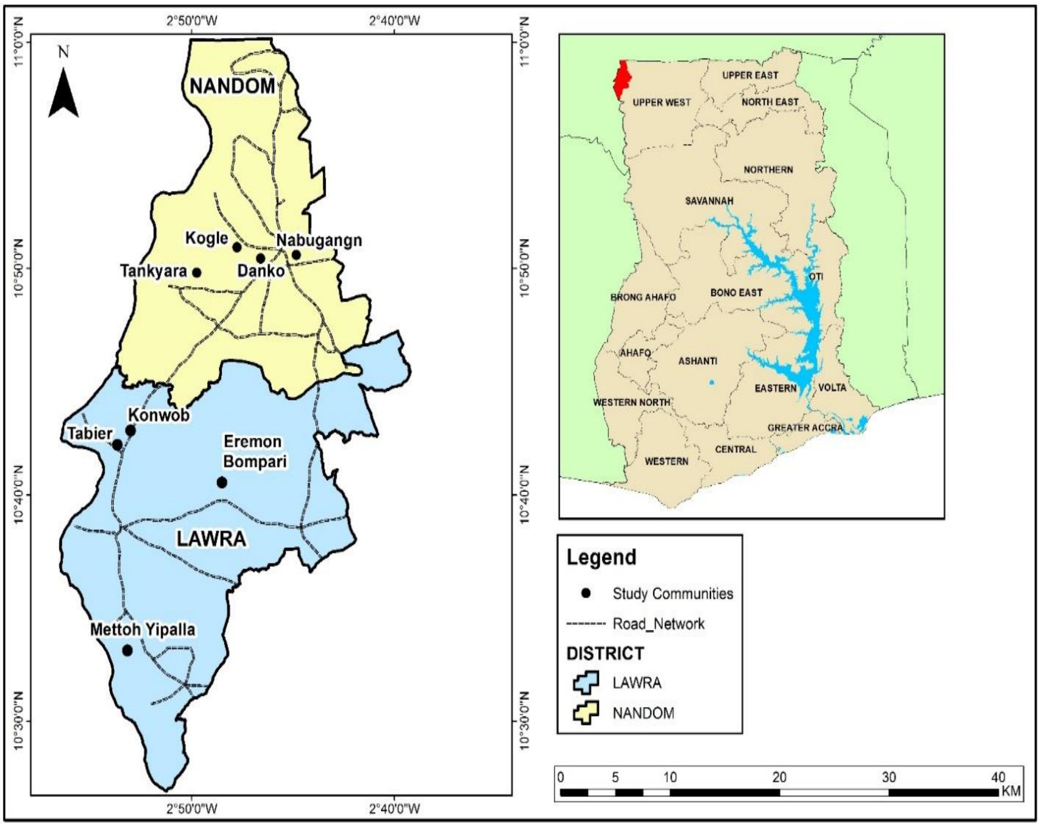

Figure 1. Map showing Lawra and Nandom and the study sites

2.2 Data Collection

A mixed method, multi-stage sampling procedure was adopted considering the nature of the study. The multi-stage process was in two-stages; a purposive and non-proportionate random sampling approach. These two municipals were purposively selected from the Upper West region on grounds that they participated in the CSA practices, and based on consultations with the regional coordinating council revealing the vulnerabilities faced by these municipals as a result of climate change impacts, coupled with a high incidence of poverty (Ahmed et al., 2016; Nyantakyi-Frimpong and Bezner-Kerr, 2015; Rademacher-schulz et al., 2014). This occurrence has resulted in these areas receiving interventions to build the resilience of the stakeholders working within the agricultural sector.

A non-proportionate random sampling technique was used to select the smallholder farmers who have been exposed and or adopted the CSA practices in these study areas. Deliberate efforts were made to maintain a balance in gender and age inclusiveness in the study to avoid bias and a simple random method was used in selecting the respondents. Both qualitative and quantitative data were collected in the study and three hundred unstructured questionnaire surveys, sixteen Focus Group Discussions (FGDs), expert consultations, observations and eleven Key Informant Interviews (KIIs) were used to obtain data for the study. The semi-structured questionnaire was used to collect the socio-economic data of respondents, awareness and farming practices adopted and factors that influenced the adoption of the various CSA practices. The CSA strategies adopted by farmers were twenty (20) and included: household tree planting, manure application, crop rotation, mulching, intercropping, manure management, improved forages, improved livestock breeds, improved crop varieties, dry season farming, minimal tillage, stone bunds, residue management, rainwater harvesting and contour ploughing (Peterson, 2014). These selected practices were also backed by expert consultations with key informants working within the agriculture works stream. The FGDs sessions involving a total of 180 discussants were held separately for males and females (8-10 in a group) in each community.

2.3 Data Analysis

2.3.1 Computing for Awareness and Rate of Adoption of Climate Smart Agriculture Practices

The descriptive statistics of the STATA software, version 14.2 was employed in the analysis. The analysis for this objective was a two-stage process, firstly, the percentage of awareness of CSA practices were calculated using the formula below;

$$\text{Percentage of awareness} = \frac{number\ of\ persons\ \ aware}{total\ number\ of\ respondents} x\ 100\% \quad (1)$$

The individual percentages for the practices were collated and described in a bar chart. In determining the adoption rate of the respective CSA practices, the formula below was used:

$$\text{Adoption rate} = \frac{number\ practising}{total\ number\ of\ respondents} x\ 100\% \quad (2)$$

The adoption rates considered for this study were categorized as either low, medium or high. A score of less than or equal to 49% was considered as low rate of adoption, while a score between 50% to 80% was considered as medium rate of adoption and a score above 80% was considered as high adoption rate. Findings from this analysis were validated during the key informant interviews.

2.3.2 Computing the Normalised Difference Water Index (NDWI) and Land Surface Temperature (LST)

The Normalised Difference Water Index (NDWI) and Land Surface Temperature (LST) were performed using Landsat images to give a more in-depth understanding and explanation of whether environmental influences contribute to the adoption of CSA interventions. The rationale for using this approach was based on previous climate-related studies that were successful in using satellite images to provide better description and explanation of land cover and land use (Benefoh et al., 2018; Varga et al., 2015). The satellite images (WGS 1984 projection) were downloaded from the United States Geological Survey (USGS) and earth explorer. The spectral resolution of Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) images is appropriate for land cover and land use assessment since it provides three infrared bands beside the natural colours (Red, Green, Blue) in the visible light spectrum (Szabo et al., 2016). Landsat 8 has a spatial resolution of 30m and radiometric resolution of 12 bits (Toming et al., 2016). The NDWI was computed using only Landsat 8 satellite images. The LST was measured using Landsat 7 (the year 2020) and Landsat 5 (the year 1990). Arcmap (version 10.4.1) Geographic Information System (GIS) software was used for the two analyses.

For the NDWI analysis, a five (5) year period was selected (2015 and 2020) to assess the changes in water content in the study area during the dry and wet season. Two spectral bands of the electromagnetic spectrum, Green and SWIR (shortwave infrared) bands were used to calculate NDWI (Xu, 2007). The index ranges from -1 to 1, where positive values indicate water content, and negative values represent no water (Huang et al., 2018). Thus, bare land, built environment, and vegetation record negative values in NDWI. NDWI value of less than 0 represents no water (McFeeters, 2013). Thus, index value closer to -1 represent no water feature and values closer to 1 indicate more water content on the surface.

Table 1 gives a detailed description of the bands and their wavelength.

$$\text{NDWI} = \frac{(GREEN\ -\ SWIR1)}{(GREEN\ +\ SWIR\ 1)} \quad (3)$$

Table 1. Landsat 8 OLI TIRS bands

Name	Wavelength (μm)	Spatial Resolution (metres)
"Coastal aerosol	0.43 – 0.45	30
Blue	0.45 – 0.51	
Green	0.53 – 0.59	
Red	0.64 – 0.67	
Near-Infrared (NIR)	0.85 – 0.88	
Short Wave Infrared (SWIR 1)	1.57 – 1.65	
Short Wave Infrared (SWIR 2")	2.11 – 2.29	

Source: Authors construct.

Since climate studies are performed within 30 years, the study selected 1990 and 2020 as the duration for analysis to detect changes in temperature rates in the study areas. LST was obtained by measuring the degree of heat emitted from the land surface in three main ways. Firstly, the thermal bands were converted from a digital number to radiance by using values in the metadata file associated with the satellite images. The next step was to convert the radiance image to satellite brightness temperature, and this was carried out to facilitate the measuring of the degree of temperature received by satellite during emission. The degree of measurement was initially measured in Fahrenheit but later converted to degrees Celsius and the LST was calculated for both dry and wet seasons. According to the District Analytical Report of the two districts, February to March was indicated as the dry/hottest season and April to October as the wet season (GSS, 2014a; GSS, 2014b).

Therefore, the satellite images downloaded for the analyses were in February (dry season) and April (wet season). Table 2 gives details of the wavelength of the respective thermal bands used for this study.

The equation used to convert the digital number (DN) to radiance units is shown below:

$$L_\lambda = (\frac{LMAX_\lambda - LMIN_\lambda}{QCALMAX - QCALMIN}) \cdot (QCAL - QCALMIN) + LMIN_\lambda \tag{4}$$

“Where;

L_λ = spectral radiance at the sensor’s aperture in (Watts//(m^2*sr*µm))

Qcal = Quantised calibrated pixel value in Digital Number (DN)

$LMIN_\lambda$ = Spectral radiance scaled to QCALMIN in (Watts//(m^2*sr*µm))

$LMAN_\lambda$ = Spectral radiance scaled to QCALMIN in (Watts//(m^2*sr*µm))

QCALMIN = Minimum quantised calibrated pixel value (corresponding to $LMIN_\lambda$) in DN

QCALMAX = Maximum quantised calibrated pixel value (corresponding to $LMAX_\lambda$) in DN

Conversion of Radiance to Temperature is calculated using the formula:

$$T = \frac{K2}{\ln(\frac{K1}{L_\lambda} + 1)} \tag{5}$$

Where;

T = Effective at satellite temperature in Kelvin

$K2$ = Calibration constant 2

$K1$ = Calibration constant 1

L_λ = Spectral radiance in (Watts//(m^2*sr*µm”)

Table 2. Landsat 5 and 7 thermal bands

Name	Wavelength (µm)	Spatial Resolution(metres)	Landsat
Band 6 (Thermal)	10.40 - 12.50	120	5 and 7

Credit: USGS, 2016.

3. Results

3.1 Socio-Economic Data

3.1.1 Socio-Demographic Characteristics of Respondents

The table 3 shows results for the socio-demographic characteristics of the smallholder farmers involved in the study. More than half of the study respondents were females, representing 53.5% and 57.0 % in Lawra and Nandom Municipalities respectively. Majority of the respondents fell within ages 41-50 constituting 41.5 and 37.0 % in Lawra and Nandom, suggesting that middle age farmers were involved in the study. Respondents that had the lowest percentage score that is 3.0% (Lawra), and 4.0% (Nandom) were within the category that was above 61 years. Farmers with less than 5 years farming experience formed the majority of the respondents at 47.5 and 39.0% for Lawra and Nandom respectively. For both municipals, majority of the respondents, 50.5% for Lawra and 47.0% for Nandom have received no formal education.

Table 3. Socio-demographic characteristics of smallholder farmers

Characteristics of farmer	**Lawra Percentage**	**Nandom Percentage**
Gender		
Male	46.5	43
Female	53.5	57
Age Groups		
19 – 30	14.5	21
31 – 40	29	27
41 – 50	41.5	37
51 – 60	12	11
61+	3	4
Farming experience		
0 – 5	47.5	39
6 – 10	32	38
11 – 15	4.5	4
16 – 20	10.5	13
20+	5.5	6
Educational status		
None	50.5	47
Primary	25.5	22
Junior High/Middle	15.5	18
Secondary	1	3
Tertiary	7.5	10
FBO membership		
Yes	49	48
No	51	52

3.1.2 Awareness of CSA Knowledge, Practices and Technologies

Figure 2 shows the cumulative percentage of awareness for Lawra and Nandom municipalities. It is evident that all the CSA practices were adopted among the respondents in the two study sites, with the cumulative percentages ranging between 94%-100%. Practices such as composting, intercropping, manure management, minimal tillage, mulching, planting on contours, residue management and stone bunds had 100% awareness level. Agroforestry and tree planting, as well as water storage or harvesting were least common practices among the study respondents.

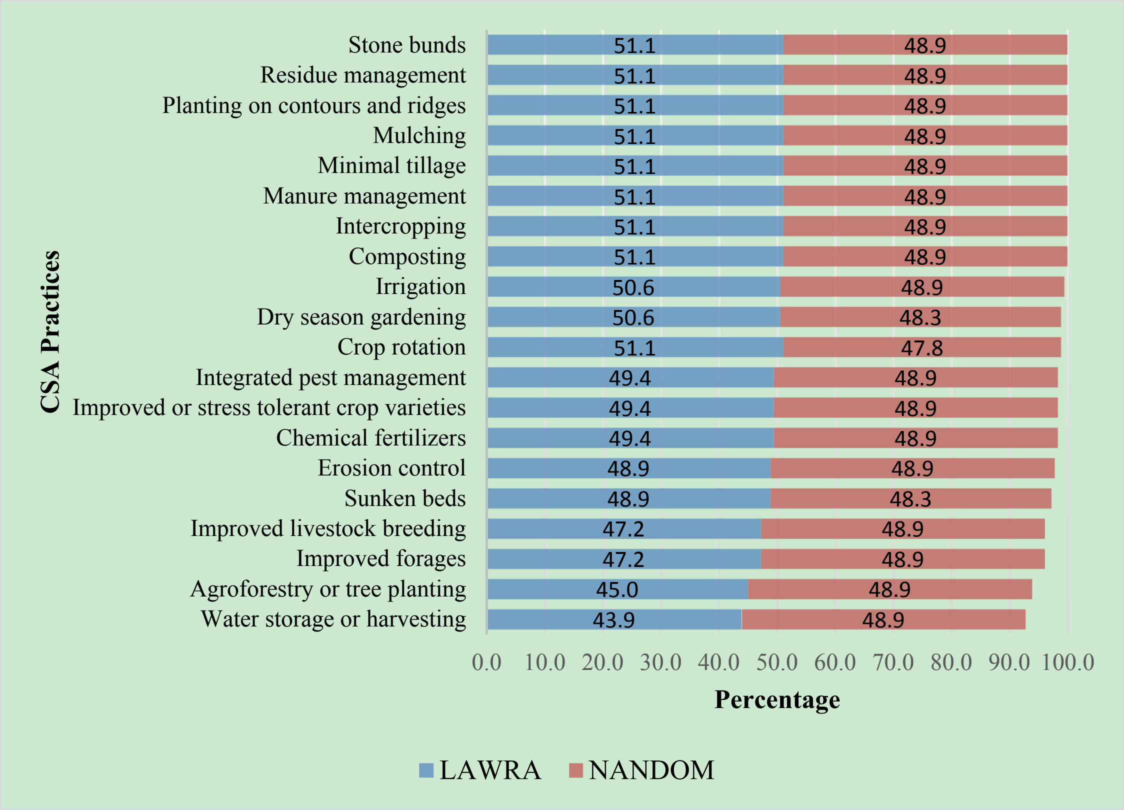

Figure 2. Awareness of CSA knowledge, practices and technologies for Lawra and Nandom

3.1.3 Rate of Adoption of CSA Knowledge, Practices and Technologies

Figure 3 shows that the majority of respondents have adopted many of the practices except for irrigation which had a low adoption rate at 31.1%. Practices such as intercropping, manure management, and mulching had a high adoption rate and scored 100%. Practices such as composting, crop rotation, residue management, chemical fertilizers, planting on contours and ridges, erosion control, improved or stress tolerant crop varieties, minimal tillage, improved forages, and integrated pest management belonged to the high adoption rate category. The respondents involved in the study moderately adopted stone bunds, sunken beds, water storage or harvesting, improved livestock breeding, dry season gardening and agroforestry.

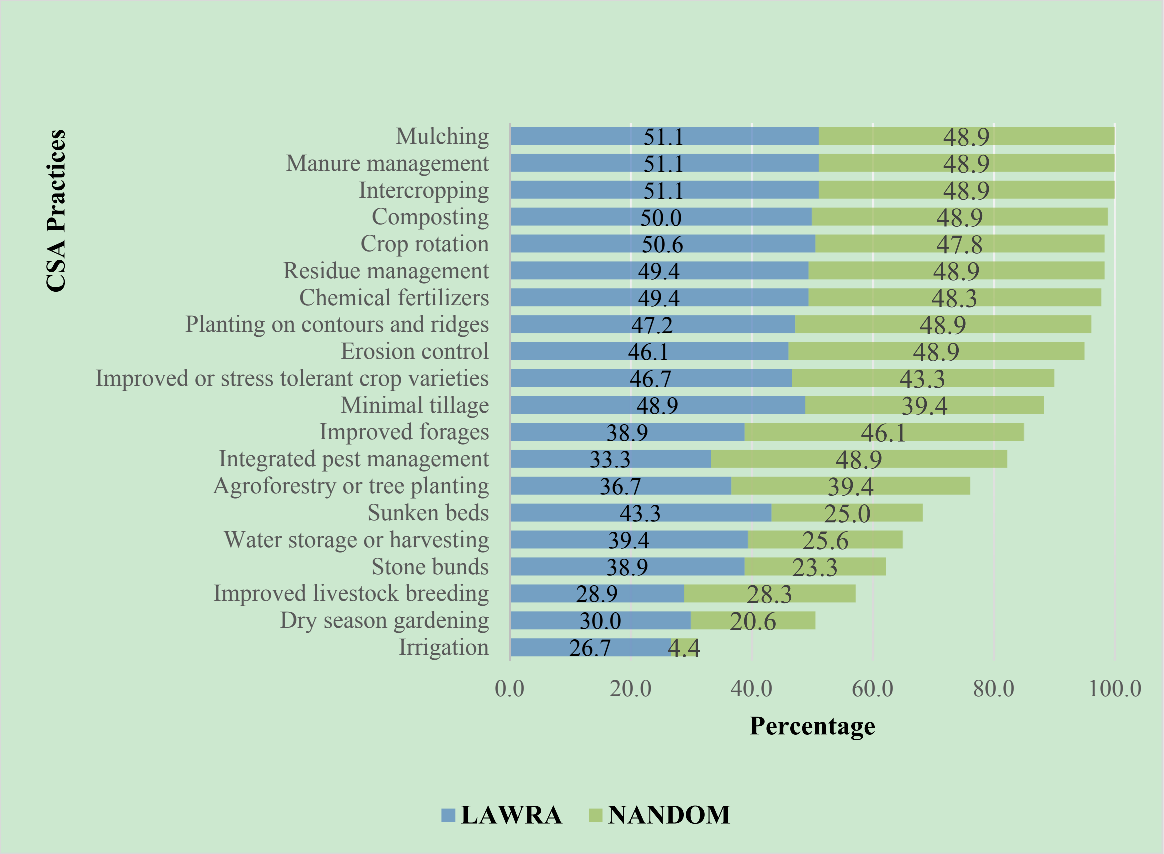

Figure 3. Adoption Rate of CSA practices, knowledge and technologies for Lawra and Nandom

3.1.4 Environmental Influences Contributing to Adoption of CSA Interventions

NDWI and LST as environmental variables affect the choice of CSA practices. NDWI shows the available surface water, while LST shows the temperature of an area. These parameters (NDWI and LST) have a higher probability of influencing farmers’ choice of viable technology relevant to their needs.

3.1.4.1 Normalised Difference Water Index (NDWI) during Dry Season

Given the NDWI values of the two municipals (Figure 4), the highest recorded in Lawra and Nandom in 2015 was -1 and -0.75 respectively. In 2020, Nandom recorded -0.85 as against -1 recorded at Lawra. It could be deduced that Nandom has a relatively higher surface water retention capacity than Lawra. Therefore, irrigation schemes are more likely to yield better results in Nandom than in Lawra during the dry season. In 2020, the percentage change in Nandom within the 5-year period was 12%. In Lawra, there was no significant change in NDWI index during the 5-year period in the dry season.

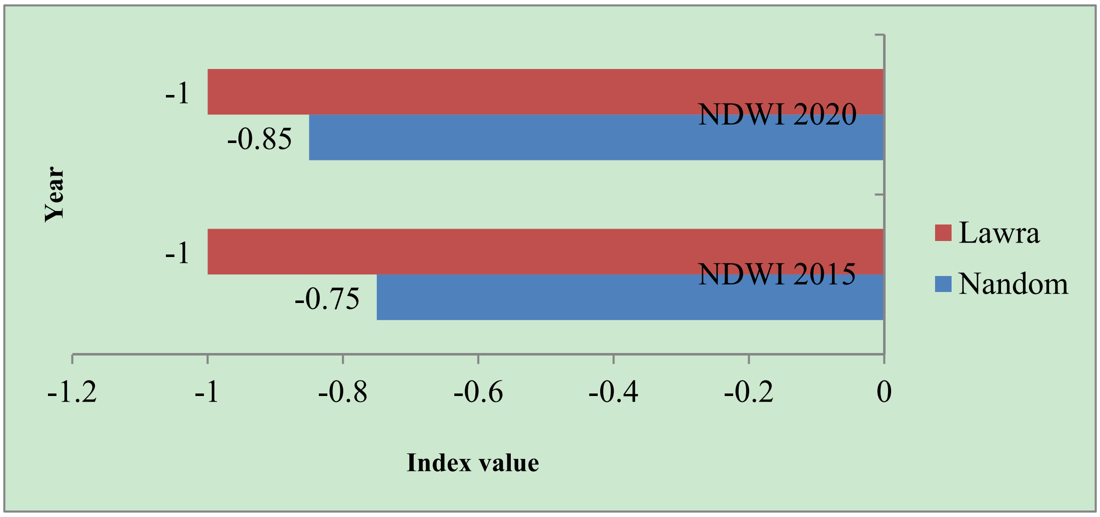

Figure 4. NDWI in the study areas during the dry season

Results of the NDWI for the respective communities show that Danko (both 2015 and 2020) has more favourable surface water content than the rest of the communities in the study areas (Table 4). The communities with very low surface water content include Kogle and Eremon-Bompari. These water bodies are made up of streams dugouts and dams that feed into the Black Volta, the backbone of the agriculture in the districts (GSS, 2014a). Since the NDWI shows the potential of surface water features despite the dry climatic conditions in the area, the streams and dugout can be harnessed to provide an all-year-round water supply for plants and livestock because results show the availability of water. Communities with surface water potential include Kogle, Nabugangn and Tankyara in the Nandom Municipal and Konwob, Tabier and Mettoh-Yipaala in the Lawra Municipal.

Table 4. Result of NDWI for 2015 and 2020 in dry season

Municipal	Community	NDWI 2015	NDWI 2020
Nandom	Danko	-0.02	-0.02
	Nabugangn	-0.19	-0.24
	Kogle	-0.28	-0.32
	Tankyara	-0.26	-0.27
Lawra	Eremon Bompari	-0.29	-0.31
	Konwob	-0.22	-0.27
	Tabier	-0.24	-0.28
	Mettoh Yipaala	-0.28	-0.29

Figure 5 shows the type of irrigation strategy adopted by farmers as 46% for river, 9.3% for lake, 1.75 for dam, 1.3% for well/dugout, 2.3% for tap water, 3% for borehole and 36.3% accounting for other sources such as rainwater harvesting in barrels.

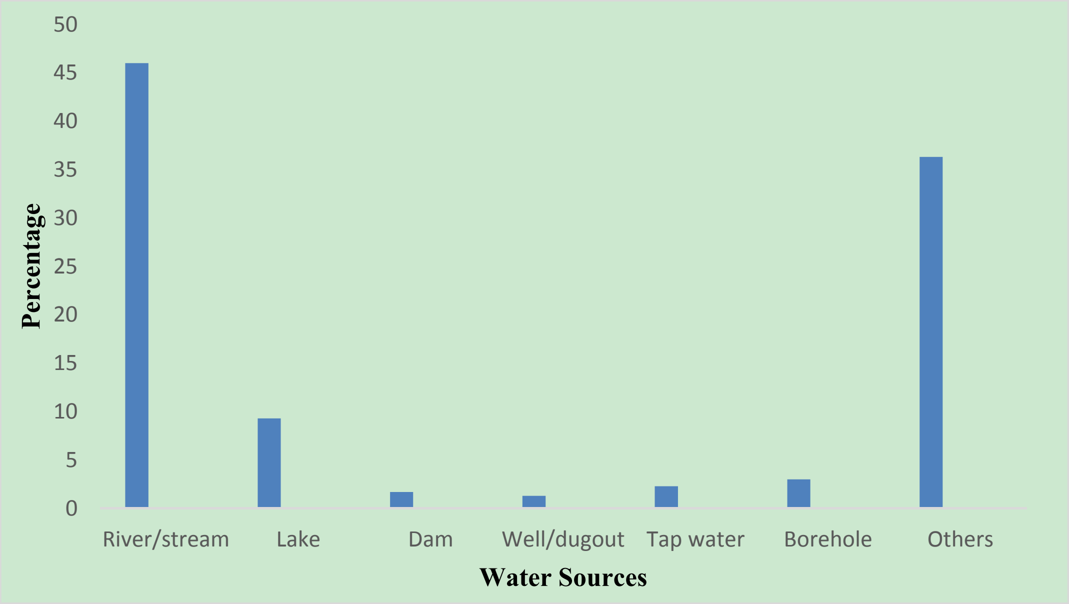

Figure 5. Percentage of water sources for Lawra and Nandom

3.1.4.2 Normalised Difference Water Index (NDWI) During Wet Season

The NDWI was calculated for the wet season using Landsat 8 satellite image for 2015 and 2020 as shown in Table 5. In 2015, the community with the highest level of surface water was Eremon-Bompari in Lawra. However, in 2020, Nabugangn had the highest potential of surface water. The communities with the poorest surface water in 2015 were Tankyara, Konwob and Mettoh-Yipaala. It is expedient for such communities to embrace irrigation strategies because of the poor retention capacity of the soil to hold water during the wet season.

Table 5. Result of NDWI for 2015 and 2020 in wet season

Muncipal	Community	NDWI 2015	NDWI 2020
Nandom	Danko	-0.21	-0.16
	Nabugangn	-0.20	-0.12
	Kogle	-0.22	-0.14
	Tankyara	-0.24	-0.16
Lawra	Eremon Bompari	-0.08	-0.22
	Konwob	-0.26	-0.17
	Tabier	-0.16	-0.18
	Mettoh Yipaala	-0.30	-0.17

Results obtained during the rainy season showed improvement in the surface water for both municipals within the 5-year period. This is largely attributed to the emergence and expansion of temporal surface water such as dugouts and streams, and an increase in the volume of permanent water bodies such as rivers. As shown in Figure 6, both Municipals recorded -0.8 water index in 2015. However, in 2020 Nandom municipal recorded -0.5 while Lawra recorded -0.74. The difference in the water index value (-0.24) means that Nandom has a relatively higher potential to retain surface water during the wet and dry seasons as compared to Lawra. This potential makes Nandom, favourable to be able to support irrigation projects. The rate of change during the wet season for Nandom was 38%, indicating a high increase in surface water within the municipality. In Lawra, the rate of change was 6%, representing a minimal increase in surface water during the wet season.

Figure 6. NDWI in the study areas during the wet season

3.1.4.3 Comparison of NDWI across the Study Areas during the dry season

Figure 7 shows the result of NDWI computed for the two study municipals over five years. Both municipals recorded a 0.1 index ratio in 2015. However, in 2016, Lawra recorded the lowest water index ratio with a value of -0.01, indicating a reduction in surface water content. Nandom in 2017, recorded the highest water index ratio and maintained that trend through to 2020. Lawra, on the other hand, recorded a 0.1 water index ratio and has taken an upsurge in 2020 (0.2 water index ratio). The trend analysis shows that even though both municipals share similar concentration of surface water features, the content of water bodies in Lawra municipal has expanded between 2019 and 2020. This presents an opportunity for farmers to utilise the available water to feed their livestock and irrigate their crops. Communities in the Lawra that will be viable for the irrigation project include Tabier, Mettoh-Yipaala and Konwob.

Figure 7. NDWI baseline trend for the study areas

3.1.4.4 Land Surface Temperature (LST) during the Dry Season

The highest temperature rate recorded for the two municipals were used to depict land surface temperature during the dry season. In 1990, the highest temperatures recorded in Lawra and Nandom were 42°C and 39°C respectively. In 2020, Nandom recorded 40°C while Lawra recorded 39°C as the highest temperature rates. There was a slight increase in temperature rate in Nandom from 1990 to 2020 (3% rate of change). Lawra municipal on the other hand recorded a reduction in temperature rate within the 30-year period (7% rate of change).

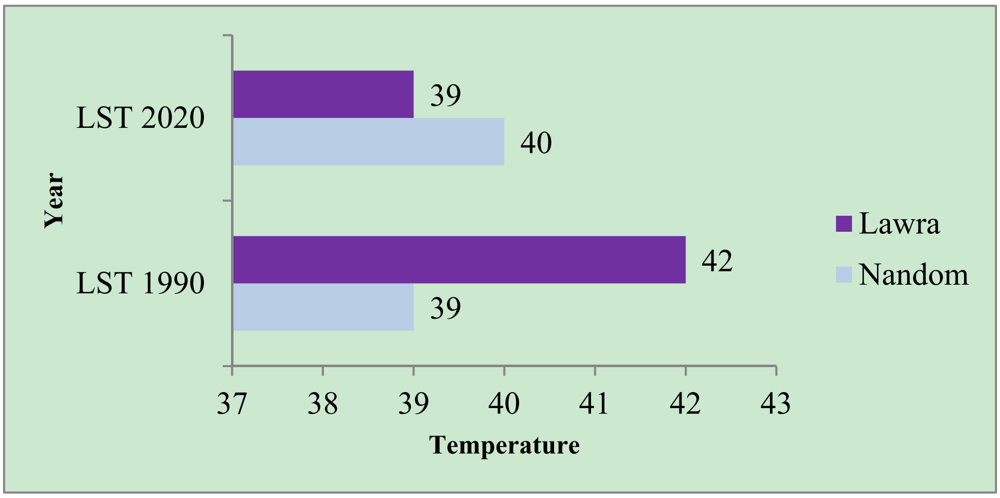

Figure 7. Highest Temperature rates recorded in the study areas during the dry season

3.1.4.5 Land Surface Temperature during the Wet Season

As shown in Figure 8, the highest temperatures in 1990 for Nandom and Lawra were 32°C and 33°C respectively. In 2020, Lawra recorded 30°C and Nandom recorded 31°C. The rate of change between 1990 and 2020 in Nandom and Lawra during the wet season was 3% and 9% respectively. Temperature rates were generally lower in the wet season than the dry season in the two municipals due to high moisture content in the atmosphere and expansion of surface water features during precipitation.

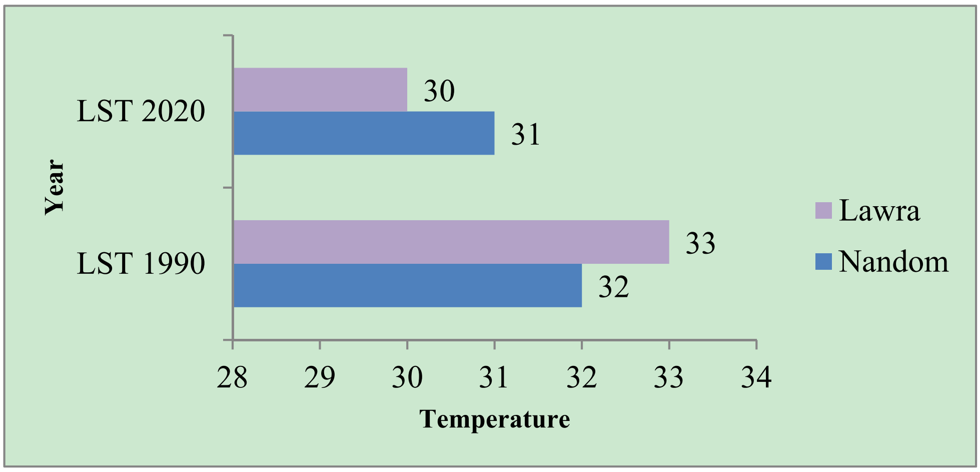

Figure 8. Highest temperature rates recorded in the study areas during the wet season

4. Discussions

4.1 Awareness of CSA Practices and the Respective Rate of Adoption

Adoption rates are hinged on subjective variables such as farmers' overall concern for the problem the CSA practices aim to address, awareness of new practices, and personal willingness to adopt the CSA practices (Below et al., 2010). Approximately 20 identified CSA practices, including knowledge and technologies, were identified for this study. As shown in our results, the averagely higher number of farmers adopting the CSA practices could have been influenced by the continuous participation by farmers in the CSA program. This is in line with Peterson (2014). CSA practices such as intercropping, manure management and mulching had a 100% adoption rate for this study. Studies by Alare et al. (2018) on CSA adoption in semi-arid Ghana revealed 100% adoption for intercropping, minimal tillage, and residue management, as compared to a study by Peterson (2014) in Lawra which found out that there was less than 100% adoption rate for similar CSA practices. The higher adoption rates could have been influenced by the age of farmers who benefited directly and indirectly from the programme. Studies have shown that young adults are better able to adopt agricultural technologies quickly than aging farmers due to the laborious nature of some of the practices (Kifle et al., 2022, Mashi et al., 2022 and Shahbaz et al., 2022). Andati et al. (2022) however found the reverse. Additionally, adoption of some of the CSA practices is a function of extra income from alternative sources of livelihood. This shows that farmers need to invest in CSA practices before they can adopt. Aging farmers who fall within the unproductive zone are unable to raise investment capital to adopt some of the practices (Ng'ang'a et al., 2021).

Findings from this study further revealed that irrigation was the least adopted practice, followed by dry season gardening (31.1% and 50.6% respectively). Finding from Peterson (2014) in a study conducted in Lawra, was in contrast with that of this study as the least adopted practices were improved livestock breeding, improved forages and stone bunds (0%, 2% and 8% respectively). Low adoption of irrigation and dry season gardening for this study was attributed to various challenges such as practices being laborious, expensive (cost for setting up equipment), high risk due to weather conditions, and restricted by limited availability or access to water, limited access to agricultural inputs (improved seeds and agrochemicals) and inadequate access to available markets for harvests. Low adoption of irrigation and dry season gardening poses an issue of food insecurity considering the fact that these study areas are located within the semi-arid region and have about 7 months of dry season.

Participants during the FGDs indicated that adoption of intercropping provided benefits such as nutrient fixation by leguminous plants; reduced risk since farmers can depend on other crops if one fails and efficient use of farm space.

4.2 Impacts of NDWI and LST on the Adoption Rate of CSA Practices or Technologies

Availability of surface water content is essential in supporting agricultural activities. Studies by Huang et al. (2018) revealed that an area with the presence of surface water content is characterized by a high NDWI value which is usually an extremely high-resolution image and hence has a high NDWI (closer to 1). Backing this assertion, is a drought severity study conducted in South Africa by Orimolove et al. (2019), which revealed that a high NDWI value indicated less drought in an area while low values are susceptible to drought occurrence. The NDWI trend analysis for both municipals revealed the availability of water content that can be accessed for farming activities during the dry seasons. Both municipals share a relatively similar concentration of surface water features (0.1), which in this case is considered higher by findings from literature. Irrigation and agricultural water management are the way forward to improving food security and incomes of smallholder farmers in response to the climatic conditions of semi-arid regions (Douxchamps et al., 2015). The respondents for both study areas indicated that the most preferred water source for irrigation activities (46%) and the dugout, the least considered (1.3%). This presents an opportunity for farmers to utilise the available water to feed their livestock and irrigate their crops.

The emergence and expansion of temporal surface water such as dugouts and streams, and an increase in the volume of permanent water bodies such as rivers have improved surface water resources in both municipalities. It is necessary that irrigation and other water management strategies need to be considered in the execution of CSA programmes in the region in a conscious effort to reduce the vulnerability of smallholder farmers to the impacts of climate change and variability. Also, the perceived challenges associated with the usage of these technologies need to be addressed and farmers sensitised on the benefits related to the adoption of these technologies.

The LST of an area is essential and has been recognised in agriculture since it has impacts on growth of crop and ultimately, the yields as well (Heinemann et al., 2020). The adoption of irrigation and other water management schemes needs to take cognisance of the LST in the area. The LST findings for the two municipals over a 30-year period (from 1990 to 2020) in the dry season show that Nandom and Lawra experienced an increase in temperature (3% and 7% respectively). This change is not surprising as the global predictions by IPCC (2022) report, shows the increase in temperature in the tropical regions. Backing this assertion are findings from EPA (2015) report that revealed that all the agro-ecological zones of Ghana have experienced an increase in temperature since 1960. A warmer temperature means that crops would require more water for growth. The Africa Chapter of the IPCC Report (Trisos et al., 2022) revealed that increase in average temperature of an area will negatively affect crops in semi-arid areas, which are already encountering yield decrease as well as increase in evapotranspiration for water bodies, soils and plants. As anticipated, results for LST for the wet season for both municipals showed a reduction of temperature within the 30-year time frame at 3% and 9% for both Nandom and Lawra respectively. This occurrence can be explained by the availability of water content and the expansion of surface water features during the raining seasons.

5. Conclusion and Policy Recommendation

The study assessed awareness of CSA forms by farmers as well as the rate of adoption of these CSA forms. The majority of the respondents were aware of the 20 identified CSA practices, knowledge and technologies considered for the study, and awareness did not necessarily transcend to the adoption of these practices. Awareness in this case refers to respondents knowing about the existence of a particular CSA practice through training sessions offered by project implementing entities such as governmental agencies and developmental partners. CSA practices such as intercropping, manure management and mulching had a 100% adoption rate for this study, and the least adopted practice was irrigation followed by dry season gardening. If irrigation was to be considered, majority of respondents preferred rivers/streams as the water source for irrigation activities while well/dugout was the least considered. The NDWI and LST analysis revealed that Nandom municipal is the most viable among the two Municipals to support irrigation projects since it has more capacity to retain surface water during the dry and wet seasons.

Based on the research findings, this study recommends that interventions by the Government of Ghana and developmental organisations/partners in the region should focus on creating more awareness as well as scale the adoption of the other useful CSA practices to reach the larger majority within the semi-arid region. The adoption of CSA practices should be mainstreamed into Municipal development plans as farmers' ability to adopt more CSA practices help in reducing vulnerability to climate change. Policy intervention by the Government of Ghana should ensure that there is the availability of information on CSA practices at the local level for smallholder farmer groups. Information on availability of agricultural inputs, benefits related to CSA adoption should be provided to farmers to encourage easy adoption of CSA. To facilitate information dissemination, the government in collaboration with the Ministry of Food and Agriculture should also engage more agriculture extension officers to provide extension services to farmers. Farmer cooperatives should be encouraged at the municipal level to facilitate information sharing and learnings.

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