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Relevant Local Climatic Knowledge for Sustainable Agro-Ecological Practices by Small- Scale Farmers in Northern Ghana

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Abstract

Local knowledge on climatic conditions which hitherto was used to predict the likelihood of weather outcomes is under threat of extinction due to lack of documentation coupled with a gradual decline in its knowledge transfer. Using participatory and ethnographic research approaches including focus groups discussion, key informant interviews, in-depth interviews, and purposively selecting small-scale farmers in the Upper East Region of Ghana, this study has identified key local climatic knowledge that would contribute to achieving sustainable agro-ecological practices. The study found that plant phenology like the sprouting of *Faidherbia albida* and the presence of *Ficus carica* are relevant for sustainable agro-ecological practices of small-scale farmers. Also, the frequency or otherwise of rains and the appearance of the water of the first rain at the onset of the rainy season presupposes the likelihood of the rainfall pattern in that year. Also, some animal and bird behaviour such as the movement of migratory birds, which was used to predict the likelihood of weather patterns or seasons, has been adversely affected by the changing climatic conditions. This knowledge is very relevant for agro-ecological practices since it enables farmers to plan ahead of seasons, which contributes to improving the adaptive capacity of small-scale farmers.

Keywords: local knowledge; agro-ecology; climate change; small-scale farmers; sustainability

Introduction and Background

Local knowledge in climatic conditions, in other words, classified as indigenous climatic knowledge, folk climatic knowledge or traditional climatic knowledge, plays a very significant role in agricultural practices of small-scale farmers. The knowledge is used to forecast weather patterns and local environmental measures (Mercer et al., 2007; Nakashima, et al., 2012; Kijazi et al., 2013) which are relevant for planning at the local level, and therefore serves as an alternative of the scientific climatic weather forecast which is less accessible to local farmers. Interestingly, this local knowledge is transferred from one generation to another through the oral tradition (Orlove et al., 2009), continued experimentation, trial and error, and sustained interactions with the local environment (Boansi et al., 2017). Although this local knowledge has been relevant and used by local people for a long time, the knowledge is under threat of extinction due to lack of documentation, no research to document the accuracy and reliability of some of the knowledge over time as well as loss of the knowledge due to death of the aged who are the main custodians of this knowledge (Orlove et al., 2009; Enock, 2013). Although science seems to have replaced local knowledge over time, the scientific knowledge has been challenged in recent times of not adequately predicting climatic events and therefore affecting farmers' ability to adequately respond to the changing environmental events in a sustainable manner (Mafongoya and Ajayi, 2017). The scientific knowledge is very expensive for the small-scale farmers, which therefore affects their ability to respond to changing climatic conditions over time.

Local climatic knowledge helps local people to plan how to use land, improve resilience and monitor weather patterns (Mercer et al., 2007; Yaro, 2013; Suiven et al., 2019). The knowledge is often associated with local and social beliefs, cumulative experience through observation of natural biotic factors or occurrences, and is unique to a given culture which informs the behaviour and practice of a group of people (Nyong et al., 2007; Orlove et al., 2009; Walshe and Nunn, 2012; Shoko and Shoko, 2013; Kijazi et al., 2013; Suiven et al., 2019). This helps them to minimise the effects of shocks and disasters on their wellbeing, especially climate-related disasters. When farmers experience a variation from the ideal (knowledge) such as the failure of the rainfall pattern or sequence at the onset of the rainy season, they take precautionary measures to stock grains or reduce farm investment since that signify the likely rainfall patterns and therefore their consequent effect on farm output or crop yield (Roncoli et al., 2002). Local knowledge is key for local-level weather forecasts, the making of informed, timely and effective decisions and agro-ecological practices, which are essential for agricultural activities and production of the small-scale farmer. Of recent times, local predictions and forecasting of weather patterns have become more challenging due to the demise of the knowledge-bearers (the aged).

Effective agro-ecological practices improve small-scale farmers' resilience, therefore ensuring high agricultural productivity as well as improving the adaptive capacities and mitigation to climate change impacts. The practice promotes effective management of the natural environment, including soil fertility, water conservation, disease control and environmental protection, that ensures increased productivity in the agricultural sector (Msaki et al., 2015).

In Ghana, the activities of small-scale farmers depend largely on rain, thereby making weather predictions key for climate-smart agricultural practices. This helps to improve the adaptive capacities, mitigation approaches and the reduction of risk of disasters, thereby improving the coping strategies of farmers. These farmers rely largely on local knowledge for agricultural activities since the conventional weather forecast outputs are technical, expensive to acquire and therefore are less accessible to the small-scale farmers (Shoko and Shoko, 2013; Kijazi et al., 2013). Scientific meteorological forecasts, which are developed by using information from global circulation models and adapting the outputs to local conditions through extrapolation with historic data, are very technical and expensive to the small-scale farmers. This minimises their benefits to the farmers and increases their vulnerability to bad weather that may lead to poor yields (Shoko and Shoko, 2013; Kijazi et al., 2013). Global Circulation Models (GCMs) have so far performed poorly in simulating rainfall in West Africa. This results in weather projections being largely uncertain (Sarr, 2012), thus affecting the activities of small-scale farmers.

This paper assesses the various aspects of the local climatic knowledge of the Kusasi tribe of the Upper East Region of Ghana. The assessment considered the knowledge that is used by small-scale farmers to predict weather patterns which are relevant for farming in the communities. The paper first identified the various local climatic indicators used for weather prediction in the communities. These indicators are grouped into three major areas: celestial phenomenon; animal and bird behaviour and; plant phenology. The discussion stage established the indicators that are relevant for agro-ecological practices in this climate uncertainty regime.

Political Economy of Climate Change

Climate change is understood and presented differently by various groups of people. While scientific decisions rely on scientific evidence, at community level, local knowledge is used to describe climate change based on observations over time. The difference in presentation and understanding of climate change goes a long way to affect the individuals affected by the phenomenon. The educated people rely on the scientific evidence while the local people rely on the local knowledge for the description, understanding and adaptation to the changing climatic conditions. This implies that actors in climate change are influenced by exposure, power, resource levels, and institutional interaction in every society (Clapp et al., 2018). Available information on climate change is often centred around technical knowledge and therefore requires technical solutions. This technical know-how negatively affects the local-level practices, due to costs and difficulty in understanding the technicality in the science.

At the lower levels, people interpret climate change by simply describing the changing climatic conditions or effects in the area. Various indicators are used to describe it, which ranges from precipitation to temperature at the local level. It is however clear that the aged are able to provide evidence of the changing climatic conditions since they are able to compare the conditions in two different time periods (Jabik, 2018). Because of the variation in the effects, communities adopt multiple adaptation strategies in order to improve resilience and reduce vulnerability. For instance, adaptation approaches used during drought conditions include growing of drought-tolerant and fast-maturing crop varieties, increasing wetlands cultivation and livestock-keeping, migration, water harvesting, buying supplementary foods and an increased emphasis on keeping small stocks (Hassan and Nhemachena, 2008; Laube et al., 2012; Kangalawe and Lyimo, 2013; Yaro, 2013; Teye et al., 2015). On the other hand, adaptation used during periods of availability of excess water or rainfall, is the cultivation of excess-water-tolerant varieties like rice (Kangalawe and Lyimo, 2013). Other adaptation approaches that farmers perceived as appropriate, include crop diversification, using different crop varieties, varying the planting and harvesting dates, increasing the use of irrigation, increasing the use of water and soil conservation techniques as well as diversifying to non-farming activities (Hassan and Nhemachena, 2008; Laube et al., 2012; Kangalawe and Lyimo, 2013; Yaro, 2013; Yeye et al., 2015). These approaches are the important forms of insurance against rainfall variability (Hassan and Nhemachena, 2008). While the aged have more indigenous knowledge, younger people are more likely to adapt to various changing climatic conditions (Jabik, 2018).

Because the effects of climate change vary as well as the type of adaptation, so too do the factors that influence adaptation of a particular approach. The most common factors that influence climate change adaptation include the age of the farmer, household size, income level, awareness of the hazards and effects of the climatic condition, ownership of land, access to both input and output markets and access to extension services (Maddison, 2006; Agrawal and Perrin, 2008; Hassan and Nhemachena, 2008; Laube et al., 2012; Kangalawe and Lyimo, 2013; Tambo, 2016). However, whichever approach is adopted to improve the resilience of farmers, there is the need to establish the influencing factors so that the impact could be maximised or scaled out.

Theoretical Framework

The theoretical framework adopted for the study is the Environmental Possibilism Theory. The theory was postulated by a French human geographer, Paul Vidal de la Blache during the early part of the twentieth century. Human societies are placed as active agents of nature due to the progressive transformational development of humankind in terms of knowledge and technology over time. The progressive development of knowledge and technology, either formally or informally, leads to an increase in the potential beneficial options available for humans to interact with the natural environment. De la Blache (1922, as cited by Ayichew, 2014) indicated that nature provides possibilities with limits. However, the reaction of man to those conditions depends on his past experience. Although climatic conditions present some challenges to human life, human beings use existing knowledge to interact with the environment for a benefit.

De la Blache postulates that, in every natural environment, there are challenges and potential benefits. Human beings within that environment have a range of potential opportunities that could be deployed to mitigate the challenges of that natural setting (Ayichew, 2014). Human beings have varied options to choose how to interact with the environment in the best possible manner for benefit. This implies that, climatic conditions do not set limits on human societies, but provide potential benefits that could be explored and deployed. Humans adapt to the changing conditions offered by the natural environment leading to different living conditions and habits (Ayichew, 2014).

As stipulated in the theory, environmental conditions do not only present challenges, but there are potential benefits that could be explored and deployed for improved wellbeing in every society. This basically looks at what human beings deploy for improved wellbeing during the era of climatic uncertainties. The tenets of this theory helped shape the assessment of climate change adaptation options as well as the knowledge and the perceived environmental changes that the people in the study area of this research encountered. This helped set the base for the understanding of the social context within which the small-scale farmers are able to identify the challenges and potential of their settings. Furthermore, the theory helped to relate the knowledge to the climate change adaptation options adopted by the small-scale farmers in the study area as well as to environmental conditions. This is so because climate change adaptation approaches adopted by a farmer are a proxy or the reflection of the application of the potential benefits of climate change in the area.

Research Methodology

The research was conducted among the Kusasi tribe in the Upper East Region of Ghana. The research adopted a purely qualitative approach. Literature was reviewed from both published and unpublished papers related to local climatic knowledge of farmers and the climate change adaptation options of farmers across the globe. This was followed by field data collection using focus group discussions with small-scale farmers, interviews with local knowledge custodians who were identified using the snowballing approach and individual interviews with selected individual farmers.

Interviews with knowledge bearers

Eight interviews were conducted with people who have adequate knowledge on climatic conditions over time in the study area. Interview guides were used to carry out the data collection. The research participants were identified using the snowball approach where the identification of one participant led to the identification of other participants. The data gathered from these individuals were used to verify with the farmers on which knowledge is relevant for climate change adaptation options.

Focus group discussions

In an attempt to understand the dynamics of climate change and the various climate change adaptation approaches adopted by small-scale farmers amongst the Kusasi tribe in the Upper East Region, six focus group discussions (FGDs) were conducted among different small-scale farmers in the region. The small-scale farmers were mainly farmers using varying climate change adaptation approaches such as dry season gardening, millet farming and maize farming. During the FGDs, farmers revealed the various climate change adaption approaches that they adopted. They also identified individual farmers in the area with information on local knowledge about climatic conditions over time. These individuals with substantial information became the potential research participants who served as key informants during the in-depth interviews.

In-depth interviews

Ten in-depth interviews were conducted among farmers who were identified as farmers with adequate knowledge on climatic conditions as well as climate change adaptation approaches within the region. Some of these farmers were also members of the focus group discussions. The data from the in-depth interviews helped to triangulate as well as gather detailed information on the data that was captured during both the interviews and the focus group discussions. It also related the knowledge of the people to the practical application in the context of climate change adaptation.

Analysis of the data

The discussions and interviews of the research participants were captured or recorded using audio equipment and field notes. The audio recordings were transcribed and the transcripts were coded. Thematic analysis was used to present the findings of the research. The codes were further used to develop themes which set the basis for the analysis and write-up of the research output.

Description of the study area

This section describes the locational characteristics of the ethnic group studied, located in the Upper East Region of Ghana. Key issues considered in this section include the location, climate, social and cultural issues and employment distribution among the people. These areas are described in detail below.

The Kusasi tribe is an ethnic group located in the eastern side of the Upper East Region of Ghana. The ethnic group is the dominant group in six districts of the region. The districts are the Bawku Municipality, Binduri, Bawku West, Pusiga, Tempane and the Garu districts. The districts are covered with three main soil types: red and brown sandy loam and clays; moderately deep, pale brown coarse sandy loams; and grey sandy loams and clays in river valleys. These soils support a variety of crop production, mainly cereals, and legumes (GSS, 2014; GTDA, 2015).

The districts fall within Zone D of the Ghana Meteorological Agency (GMet) agro-ecological classification and the interior continental climatic zone of the country characterised by uni-modal rainfall seasons from May/June to September/October and the dry season from October/November to April/May (Owusu, 2018). The two seasons are influenced by two alternate air masses. The cold, dusty and dry harmattan air or the North East Trade winds that blow mostly from late November to early March in the north-eastern direction. During that period, rainfall is entirely absent and humidity is very low, sometimes less than 10mm and relative humidity rarely exceeds 20% during the day but may rise up to 60% during the night and early morning (GTDA, 2015; Owusu, 2018).

The second air mass, laden with moisture from the Atlantic Ocean, blows between May and October. The air mass, together with rising conversion currents, provides the districts with rains. The rainfall is often erratic, torrential and unpredictable, rendering forecast very difficult for farmers. The average amount of rainfall is between 800–1000mm per annum with about 90% of the rainfall occurring between June and September. The large quantity of rainwater is normally lost through evapotranspiration from open surfaces, partly due to the bare and dry nature of the ground. This affects the availability of water for agriculture and domestic consumption. The lowest mean temperature is 18^0C, occurring in December/January and the highest mean monthly temperature is 40^0C in March/April (GTDA, 2015; Owusu, 2018).

Agriculture is the dominant occupation of the Kusasi people with about 85.2% of the active labour force engaged in it (GSS, 2014). This makes agriculture the main dominant occupation which is often rain-fed. The over-reliance on rainfall for farming has made agriculture highly vulnerable in the area (Yaro, 2013). Both women and men play a significant role in farming activities in the area. The major crops cultivated by farmers are maize, sorghum, millet, groundnuts, onions, cowpea, sweet potato and watermelon. The livestock raised by farmers are pigs, cattle, sheep, donkeys, and goats. Poultry-rearing, especially guinea-fowl production, is significant in the area. The long dry season coupled with an inadequate number of irrigable dams compel the farmers to engage in shallow irrigation throughout the area. The shallow irrigation practice in the area has improved on the resilience level of some of the farmers (GSS, 2014; GTDA, 2015; GoG, 2015).

Local Climatic Indicators for Weather Forecast

Some knowledge bearers among the Kusasi people are able to predict the likelihood of certain climatic conditions using local and cultural knowledge. Some of these conditions include the onset of the rains, the cessation of the rainy season, temperature changes over time and the crops that are likely to have higher yields. Using celestial or natural phenomena, weather patterns, animals' behaviour and plant phenology over time, the knowledge bearers are able to foretell the likelihood of climatic conditions, enabling farmers to plan ahead of the farming season or during the farming period. Observations are combined with local beliefs and cultural knowledge to predict the likely consequence and outcomes of climatic conditions over a period of time. These observations span from one season to another. The local-level indicators and knowledge therefore make the environmental possibilism very relevant in the study. Analysis of the local indicators among the Kusasi people focused on general variables used by the local custodians to predict the outcome of any climatic situation. The analysis is captured according to the prevailing and well-known local information. This is further explained by the behavioural signs of the indicators which are used to predict the outcomes. The likely consequences of the occurrences of the indicators could be a seasonal forecast of weather patterns, disaster occurrences through early-warning systems and likely crop yields.

Five broad local indicators with several variables are used to predict the outcomes and likelihood of weather conditions in the area. The indicators are celestial phenomena; weather observation; plant phenology; bird and animal behaviour; and water bodies and their appearance. The various indicators and their sub-variables are discussed below.

Celestial phenomena

Celestial phenomena like wind direction, the appearance of the moon and the position of some stars in the atmosphere are used to determine the likely weather outcomes in the communities. The direction of the wind, like the south-west to north-east winds and the north-east to south-west winds signals the change from one major season to another. The south-west to north-east winds are indicative of the onset of the rainy season is closer. It is believed that the south-west to north-east winds lead to accumulation of clouds in the east, which result in rain. This wind is experienced around March/April and is used to predict the onset of the rainy season. The winds are also associated with a change in the weather pattern from the harmattan season to the hot season. The intensity and duration of the winds (south-west) before the first rains also help to determine the likelihood of dust storms that could occur during the first rainfall period as well as the volume of rainfall in that year. A farmer indicated that:

> We got to learn from our fathers and grandfathers that when the early rains are about to set in, the wind blows to the east. As such, when we experience the winds, we know the rainy season is approaching. They also told us that, heavy rains are normally associated with less wind. So, when the clouds are gathered together without heavy wind, then we know there will be heavy rains in that particular year (Key informant, 2019).

The north-east to south-west winds are often experienced around October/November and have often been used to predict the cessation of the rainy season and the start of the dry season.

The lunar months – based on certain months of the year named after specific shapes of the moon – serve as a very vital natural feature that is used for decision-making by small-scale farmers among the Kusasi people. The names of the months depict the predominant weather conditions, economic or social activity during that month. As such, the first few days at the onset of the moon, forms the basis for the likely weather conditions of that month. The moon at the onset appears in the form of a sickle, and depending on the orientation of the month, it is used to predict favourable weather conditions, disaster or inadequate rains during that lunar month. The sickle moon concave to the south or north is used to predict drought or floods, depending on the naming of the moon.

Another celestial phenomenon used for farming decisions is a 'line of clouds' (north to south) observed in the sky at night. It divides the sky into two parts and is believed to be changing position during seasons. When the rains are about to set in, the half to the east becomes larger than the half to the west, and when the dry season gets closer, the half to the west becomes larger than the half to the east. When any of the above is observed, farmers begin to plan appropriately. They either start preparing their lands for the rains if they observe that the rains are about to set in, or they start dry season activities like preparing the land for dry season gardening.

Weather observation

The appearance and occurrence of certain natural weather features like the fog, the extent of heat in the warm season, lightning and thunder during certain periods of the year, the onset of the first rains and hazy weather conditions are used to predict the likelihood of the weather pattern over time. The fog for instance, is used to predict two different likely weather outcomes depending on the season it is observed in the communities. When the fog is observed around May and June (onset of the rains) the implication is that, rains will soon set in with higher chances of a good rainfall pattern in that year. But when it is observed around September, then the chances of the rains ceasing early are higher. One of the elderly people in one of the communities indicated that:

> When the "kpaandug" comes around May and June, then soon after that there will be heavy rainfall (Key informant, 2019).

The observation of the rainfall pattern over time has also been used to predict the likelihood of the rainfall in the succeeding year. Experiencing frequent rainfall at the onset of the rainy season (three times a week) coupled with warm weather, imply a higher likelihood of normal rainfall during the rainy season, but cessation will be earlier than usual. In one of the focus group discussions, the participants indicated that:

> When there is too much heat in the lean season, and also when it rains heavily continually for three times a week, then we say that there will be heavy rains that year (FGD, 2019).

The onset and cessation of the rainy season has also been used to determine the likelihood of the volume and pattern of rainfall in that year. When early cessation of rainfall (around September or October) is observed in a year, the chances of there being early onset of the rains in the succeeding year are higher. Erratic rainfall is expected in a year if they experience infrequent rains at the onset of the rainy season during that year. When the rains at the onset are experienced with storms, there is also the likelihood that there will be an erratic and inadequate volume of rainfall in that year. One of the research participants buttressed this knowledge:

> Heavy rain is normally associated with less wind; so, when the clouds are gathered together without heavy wind at the onset of the rainy season, then we know there will be heavy rains in that particular year. But when the clouds gather and there is heavy wind then we suspect that as for that year there will be less rainfall (Key informant, 2019).

The formation of clouds has also been used to pre-determine the likelihood of storms, or otherwise. When the rain threatens and the clouds appear red at the onset of the rainy season, the likelihood of there being storms during that year is higher. Also, experiencing rainfall around September without heavy clouds or the threat of rain is an indication that the rains will cease early in that year. A key informant indicated that:

> When the dry season is approaching, we normally experience sudden rains where the clouds don't gather before it rains with too much sunshine (Key informant, 2019).

The rainfall pattern at the onset of the rainy season again has been used to predict the likelihood of drought, or otherwise for that year. The timing and frequency of succession of the rainfall predetermines the spread and consistency of rainfall in that year. Besides, the appearance of a rainbow during the first rains at the onset of the rainy season signifies the likelihood of drought in that year. A participant indicated that,

> When there is a rainbow around the clouds for the first and second rains at the start of the rainy season, then we know drought is likely to be experienced in that year. Also, during the onset of the farming season, if the rains fail to fall consistently for three consecutive times soon after cultivating crops, then it indicates there will be drought (Key informant, 2019).

Observing the rainfall patterns over time has also revealed that the rains are now two months behind, compared to what they used to know some years back. In other words, farmers then plant two months later than they used to plant in the past. With this knowledge, when they experience rains in March or April, the implication is that they will experience drought when the main rainy season starts in June. Any rainfall earlier than June is an indication that they are likely to experience erratic rainfall in that year. The planting activities two months later, translated to farmers experiencing a shorter rainy season and a longer dry season. The shorter rainy season also resulted in more frequent floods than before. Effectively, farmers therefore have four months to farm, unlike in the past where they had about six months. A farmer revealed that:

> Before the changes we are experiencing, we [farmers] knew that the dry season started from January to April. But now, the dry season covers from December to almost June. Sometimes it will be either at the middle of June or ending of June that we will start planting. Farmers now have June, July, August and September that they can be sure of the rains. And this comes with the floods (Key farmer, 2019).

Other weather features like experiencing extensive heat-waves accompanied with lightning around March, are an indication of a higher likelihood of the early onset of the rainy season. Also, experiencing hazy weather in October is an indication of the setting in of the harmattan season and therefore early cessation of the rainy season. The above features imply that farmers use multiple weather observations to draw conclusions on the likelihood of the climatic conditions in the communities.

Plant phenology

Plants generally respond to climatic conditions in various ways. Depending on the type of plant, the sprouting or shedding of its leaves shows a change from one season to another. Plant phenology such as the sprouting of leaves of certain plants, shedding of leaves, flowering and maturing of fruits of plants are used to predict the likelihood of the weather pattern as well as the likelihood of the crops that would have a bumper harvest in a year. Two reverse plant phenomena were observed among the plants used in the study. While the sprouting of leaves of the winter thorn is an indication of the setting in of the dry season, the sprouting of leaves and flowering of other plants like the shea tree, the *dawadawa* tree, and the black and yellow berry trees signify the end of the dry season. Again, the flowering of grasses is an indication that the dry season is setting in. Also, the bearing of fruits of the shea tree and the black and yellow berries is also used to predict the likelihood of a crop yield in that year. Well-fruited trees like the *dawadawa*, shea and the yellow berries imply favourable conditions for crops to yield well while poorly-fruited trees signify hardship and low outputs in that year. When the fruits of the shea tree, the *dawadawa* and the yellow berries also start maturing, the onset of the rainy season is at hand. In one of the focus group discussions, a participant indicated that:

> When trees like shea nuts, yellow berries bear more fruits, then it's also a sign of good yield of crops like early millet, late millet, sorghum, rice and beans (FGD, 2019).

The flowering of other plants like the mango trees (local variety) around November signifies that the dry season will soon set in while the flowering and fruiting of that same plant in the rainy season (June/July) signifies a likelihood of floods in that year. This implies that the timing of the flowering and fruiting of the mango tree is interpreted in two ways: an end to the rainy season or the likelihood of a flood-related disaster if experienced in June or July. Other plants like the presence of the *kinkang* tree (fig tree) signifies the presence of a high underground water table around that area. People drill wells or select crops that require much water, like rice, to plant around such areas.

Animal and bird behaviour

The behaviour of both birds and animals plays a key role in weather pattern outcomes among the small-scale farmers. The presence of migratory birds, the direction of their movement, as well as the appearance of wild herbivores in the communities, signal some likelihood of weather outcomes. Birds such as the African grey hornbill, the *cucoo*, the African masked weaver birds, and the white cattle egrets are used to predict the change from one season to another. The movement of the African grey hornbill to the north (desert) signals that the rains are about to set in while their return to the south indicates the cessation of the rainy season. It is also believed that the *cucoo* birds only make sounds when the rains are about to set in. In one of the focus group discussions, a participant indicated that:

> By listening to some singing birds like the *cucoo*, farmers begin to prepare their farmlands for planting (FGD, 2019).

When groups of the white cattle egrets are observed to be migrating from the east to the west, it implies that the rains are about to cease while their migration to the east signifies cessation of the rains. The presence of groups of the African weaver birds in the area, implies that the onset of the rainy season is close. The presence of the birds also signifies good yields of the early millet and farmers therefore plan accordingly.

The presence of other animals like some termites (*Isoptera*) in an area is an indication that underground water or the water table is high in such areas. Again, when many ants (*Lasius niger*) are observed during the onset of the rainy season, it signifies that they will experience much rains in that year. When the black ants (*Lasius niger*) are observed carrying their larvae from lower land to higher grounds (by the riverside), it signifies the likelihood of flooding in the next few days. Also, the presence of large numbers of house flies during the onset of the rainy season signifies the likelihood of a bumper harvest of early millet in that year. With this knowledge, farmers plan what crops to plant and how to manage their farms over time.

The presence of aquatic animals such as crocodiles and the fish in muddy ponds and other water bodies, is regarded as 'gods' of the communities that must be pacified and preserved. The belief is that such animals are sent by their ancestors, and should therefore be received and protected. Hitherto, such water bodies were protected and there was always water in such areas all year round.

Water bodies and their appearance

The colour of the water of the first rains has also been used to signify either drought or the likelihood of the crops that should be planted in that year. If the water is observed to appear whitish, it has two different implications. On the one hand, it implies that the likelihood of drought is higher as the planting of crops that can withstand drought, is encouraged. It also implies that crops such as millet, have better chances of having higher yields in that year than other crops. If the water is observed to be black, then crops such as guinea corn, are anticipated to have a good yield, as explained during one discussion:

> When the first rain falls, we use the colour of the water to determine which crop will do well before we even start sowing the crops. If the water is white, it means millet will yield well; if the water is black, it means the sorghum (naga red) will have good yield. Then we cultivate more of that crop (FGD, 2019).

Relevant Local Climatic Knowledge for Agro-Ecological Practices

This section presents the relevant local climatic knowledge for sustainable agricultural practices in this era of climatic uncertainties. Although a number of indicators are used for predicting and forecasting of weather patterns, not all could be relevant in this era of climate change. Preliminary discussion with the participants established some indicators that are relevant, which are discussed below. The indicators are presented according to the various thematic areas identified. These range from weather observation to animal and bird behaviour.

Relevant celestial phenomena for agro-ecological practices

Some of the celestial phenomena play very relevant roles in achieving sustainable agro-ecological practices in this era of climate change that has come with numerous uncertainties and lack of scientific evidence to project the outcome into the future. There is the need to monitor the occurrence of these phenomena in order to further explain the reality or otherwise. The direction and intensity of the south-west and the north-east winds which are used to predict the likelihood of storms and the cessation of the rainy season are relevant for preparing disaster risk reduction measures as well as preparing for dry season farming, which has become a very key adaptation approach in the communities. The intensity of the winds has also encouraged farmers to grow trees, which serve as wind breaks, on their farms.

The appearance of the sickle moon can be interpreted and used to improve on the adaptive capacities of small-scale farmers. This is so because, if the prediction would result in a disaster, farmers plan ahead of the month to accommodate the unexpected events. For instance, if the interpretation is a higher likelihood of a drought, farmers plant drought-tolerant crop varieties and if floods are anticipated, farmers can harvest some of the crops before the disaster occurs.

Also, a ‘line of clouds’ observed by the farmers can serve as very vital information for climate-smart agricultural practices. The changing from one season to another based on that knowledge, enables farmers to adequately prepare or plan for the next season to come. For instance, if the observation indicates that the onset of the rains is closer, farmers start preparing their land and if the observation indicates that the cessation of the rainy season is at hand, farmers who engage in dry season farming begin to prepare their lands. Farmers who adapt to the changing environmental situation by engaging in dry season farming use this sign to begin the preparation of the nurseries and beds for dry season gardening.

Relevant weather indicators for sustainable agro-ecological practices

The observation of the decrease in the duration of the rainy season implies that farmers should move away from planting long gestation crop varieties to short gestation crop varieties. The observation also implies that excess moisture crops should be promoted since the chances of flooding have increased due to the short rainy season.

Observing the signs for the onset and the cessation of the rains is also relevant, since farmers use those signs to start the dry season farming activities as well as to prepare their lands during the rainy season. Additionally, a long duration of the warm season and lightning experienced before the onset of the rains, signifies a shorter duration of the rainy season. This helps farmers to prepare their lands and to plant short cycle crops instead of the long cycle crops that were grown previously.

Relevant plant phenology for agro-ecological practices

Plant phenology is relevant for sustainable agricultural practices as well as agro-ecological practices. The behaviour of the winter thorn tree is very relevant for predicting the onset and the cessation of the rainy season, which is used by farmers to plan appropriately. Farmers who are engaged in dry season farming use the sprouting of leaves of the plants to begin nursing their seedlings and preparing the land for farming. One key climate change adaptation approach adopted by farmers in the area, is dry season gardening or farming, using shallow wells and along the river banks. When farmers observe that the plant has started shooting fresh leaves, they begin preparing beds and nurseries of the dry season garden crops like onions, peppers, tomatoes and garden eggs. The sprouting of leaves by the winter thorn tree when other plants shed their leaves is also very relevant for climate change mitigation since it has the tendency to increase the chances of carbon sink in the communities. The leaves and fruits of the plant are also used as animal feed thereby increasing access to animal feed during the dry season.

The presence of the *kinkang* tree (fig tree) in certain locations is very relevant for climate change adaptation practice like dry season farming since the farmers can drill wells and use that water for dry season gardening or farming. The trees grow where the water table is high or near the soil surface, which signals where to site wells and where water demanding crops could be planted.

Other plant-related indicators such as the sprouting of leaves and the flowering of the shea tree, the *dawadawa* and yellow berry trees are still relevant for climate-smart practices. The behaviour of the plant enables farmers to start preparing their lands either for the main farming season or the dry season farming activities. The flowering of the mango plant is also a relevant sign for both dry season farming and planning for disaster preparedness.

Relevant plant and bird behaviour for agro-ecological practices

Relevant local knowledge on animal and bird behaviour for sustainable farming practices could be identified from the above signs. The presence of some termites (*Isoptera*) is a very relevant indicator since it is used to determine the level of the water table underground, especially during the dry season. Farmers use that sign to drill shallow wells, which are used for dry season farming in the communities. Also, the behaviour of black ants (*Lasius niger*) could be relevant as an early warning signal for disaster preparedness like floods. When farmers observe the movement of the ants, they can begin to move upland.

The presence of aquatic animals such as crocodiles and some fishes in ponds and other water bodies can be used to protect the water bodies and their surroundings, thereby promoting clean environmental practices in those areas. According to local knowledge, the presence of such animals in water bodies is regarded as 'gods' that must be pacified and preserved. The belief is that such animals are sent by their ancestors, and they should therefore be received and protected. Previously, such water bodies were protected and there was always water in such areas all year round. The preservation approach can still be relevant in this era of climate change since it will serve as both mitigation and adaptation purposes.

Relevant water body indicators for agro-ecological practices

The colour of the water during the first rains and in the Tariganga River, which is interpreted to have implications for drought or the type of crops to grow in that year, is very relevant for sustainable practices. If the water is observed to be white, there is the likelihood that farmers will experience drought during that year. This presupposes that farmers should plant drought-tolerant crop varieties. If drought is expected in any year, then farmers prepare by acquiring the drought-tolerant varieties for planting.

Conclusion

The local knowledge has been used to mitigate the effects of changing climatic conditions, including disasters like floods, drought, crop failure and coping with challenging weather patterns over time. The experience of the changing climatic conditions has also broadened the planning horizons of small-scale farmers among the Kusasi tribe in the Upper East Region of Ghana. Local knowledge in weather and climate prediction has been used by small-scale farmers to cope with and adapt to the increased frequency and magnitude of extreme climatic events such as drought, floods and storms. Using various environmental and astronomical indicators such as celestial phenomena, plant phenology, animal and bird behaviour and weather conditions, custodians of the knowledge are able to predict weather outcomes that are relevant for farming. Based on this knowledge, farmers make important decisions about the crops they select and when to plant them. The observation of the local climatic variables enables the custodians of the knowledge to predict the likely weather patterns, which could be a seasonal forecast, the occurrence of a disaster, crop failure and levels of water tables underground, amongst others. While some of these signs and ideas are still relevant in the era of climate change, others are now difficult to be observed and are not visible and do not play any important role in weather prediction. The study has also identified emerging signs, like the reduction in the duration of rainfall and the appearance of a wild herbivore that has emerged, to be new signs that are used to predict weather patterns. Exploring for further relevant local climatic knowledge and fusing it with modern weather forecasting will contribute to improving the adaptive capacity of small-scale farmers, since modern weather forecasting is expensive, inaccessible and not clear to the small-scale farmer.

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