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Effects of Perceived Relative Advantage and Complexity on Sustained Adoption of Indigenous Weather Forecasts in the West Usambara Mountains, Tanzania

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ABSTRACT

Agriculture is a climate-sensitive economic sector that requires reliable and precise weather information to enable farmers to cope with seasonal weather as well as adapt to climate change to increase yields. In the West Usambara Mountains, the Climate Change Agriculture and Food Security (CCAFS) project promoted the integration of indigenous weather forecasts with scientific weather forecast services from 2011 to 2019. The project aimed to enhance the availability and precision of weather information for reducing agricultural risks and losses posed by climate change. The objective of this study was to assess the effects of perceived relative advantage and complexity on sustained adoption of indigenous weather forecast services after phasing out of the CCAFS project. Specifically, this study determined sustained adoption of indigenous weather forecast services, evaluated farmers' access to indigenous weather information, and examined the effects of perceived relative advantage and complexity on sustained adoption. The study was anchored on the diffusion of innovation theory. A cross-sectional research design employing both qualitative and quantitative approaches was used. Simple random sampling was used to select 124 households from 140 farming households that participated in the CCAFS project. Data were collected through household questionnaire surveys, interviews, and focus group discussions. Data analysis was done using descriptive statistical analysis and binary logistic regression for quantitative data and thematic analysis for qualitative data. Results show that sustained adoption of indigenous weather forecast services was 66.1%. Farmers had good access to indigenous weather information from peer-to-peer farmers and elders. Perceived relative advantage in increasing crop productivity increases the likelihood of sustained adoption of indigenous weather forecast services (β_1=3.777, p=0.003). Perceived complexity in terms of difficult-to-use an innovation reduces the likelihood of sustained adoption of indigenous weather information services (β_3=-3.577, p = 0.008). Perceived relative advantage in cost reduction (β_2=0.354, p = 0.766) and perceived complexity in understanding innovation (β_4=-1.422, p = 0.365) had no effects on sustained adoption of indigenous weather forecast services. The study concludes that farmers' perceptions of relative advantage and complexity are important in promoting the adoption sustainability of indigenous weather forecast services, particularly in the West Usambara Mountains. It is recommended that policymakers, agricultural extension workers, and other stakeholders integrate farmers' perceptions of relative advantage and complexity when designing, promoting, and disseminating indigenous weather forecast services to increase yields regardless of change in climatic and weather conditions.

Keywords: Agriculture, Climate Change, Climate Change Adaptation, Indigenous Weather Forecast Services, Sustained Adoption

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I. INTRODUCTION

Climate change, due to increasing the frequency and intensity of extremes, has reduced crop production, which ultimately hinders efforts to meet Sustainable Development Goals (Intergovernmental Panel for Climate Change [IPCC], 2022). Climate change has slowed the growth of the agricultural sector over the past 50 years globally. Increased weather and climate extreme events such as prolonged droughts, cyclones, hurricanes, floods, and increases in pests and diseases have subjected millions of people, especially small-scale food producers in Africa, Asia, and Central and South America, to acute food and water insecurity (IPCC, 2022). Weather information services are among the climate change adaptation measures used to reduce agricultural risks and losses posed by climate change (Lyamchai et al., 2011; Soropa et al., 2015; Jiri et al., 2016). In most cases, advanced scientific knowledge of predicting climate change and seasonal weather conditions has been disseminated to farmers and pastoralists to enable them to cope with variability in weather conditions and adapt to climate change (Gilberthorpe and Hilson, 2014; Dejene and Yetebarek, 2022). However, Radeny et al. (2019) noted that still there is a significant gap in the provision of precise, location-specific, timely, and user-friendly climate and seasonal weather forecast information that can meet the needs of farmers.

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Scientific weather forecasts do not often reach many farmers, especially in rural areas where there is low coverage of radio stations (Soropa et al., 2015). Additionally, scientific weather forecasts usually generalize weather information to a wider area, and thus it makes predictions less effective for decision-making at the farm level (Gwenzi et al., 2016). In this regard, most farmers rely on indigenous knowledge when forecasting and interpreting seasonal weather conditions based on their culture and locally available biotic and abiotic indicators (Orlove et al., 2010; Soropa et al., 2015). Indigenous weather forecasting systems are dynamic and built on observation and many years of experience (Ebhuoma and Simatele, 2017; Agyekum et al., 2022). The importance of indigenous knowledge transcends the culture from which it is born and offers insights to scientists, researchers, and others who support the livelihood of smallholder farmers (Ayal et al., 2015). Decisions of rural farmers about agricultural activities, including timing of planting, seed selection, pasture management, and number of livestock, are highly interlinked with the availability of precise and reliable weather information, particularly that originating from indigenous weather forecasts (Ayal, 2017).

A single indicator of weather forecasts is insufficient to predict weather conditions; instead, forecasting involves information from different sources in triangulation with information from modern weather forecasting services to enhance the accuracy of predictions and informed livelihood decisions (Balehegn, 2016). In southern and northeastern Ethiopia, the Gabra and Afar farmers and pastoralists use biotic forecasting instruments such as livestock, insects, birds, trees, wildlife, and the intestines of slaughtered animals, and abiotic instruments such as wind, clouds, and star assemblages when predicting weather and climate variability through observation of behaviour and patterns (Ayal et al., 2015; Balehegn, 2016). In Southern Africa, farmers use tree phenology, animal behaviour, wind circulation, cloud cover, and other social indicators to predict the onset, termination, and amount of rainfall and seasonal quality (Jiri et al., 2016). The Shona people in Zimbabwe make reasonable forecasting of seasonal weather conditions through observation of changes in behaviour and patterns of phenomena such as trees, birds, frogs, animals, insects, grass, wind, moon, lighting, and the sun since relying on the scientific methods does not always provide accurate weather estimates (Muguti and Maposa, 2012).

In Tanzania, farmers demand weather information to understand amounts, intensity, duration of rainfall, crop selection, the onset of drought, as well as choosing coping strategies to seasonal weather conditions and climate change adaptation in agriculture (Elia et al., 2014). Farmers also need information about the severity of the sun, drought, and rainfall to make appropriate farm-level decisions (Ayal et al., 2015). Biological indicators are based on seasonal changes in plant and animal behaviour and patterns (Zuma-Netshiukhwi et al., 2013; Elia et al., 2014). The study conducted by Radeny et al. (2019) reported various biotic and astronomical indicators used for indigenous weather forecasting in the West Usambara Mountains. The occurrence of large flocks of swallows and swans roaming from the south to the north between September and November is an indication of the onset of short rain within two to three days. Coucal singing out loud indicates short rains, while singing an owl in the sky is associated with a planting season. The occurrence of yellow birds is an indication of the long rains. Migration of wild animals such as baboons, monkeys, leopards, and antelopes coming into the village during the dry season indicates good rains in the coming season. The occurrence of flying ants (*Odentotermes* spp.) after strong sunshine is a sign of the onset of proper rains sufficient for planting with adequate soil moisture. Heavy flowering of fruit trees like pears indicates the rainy season. The appearance of insects locally known as *vidododo* on an Albizia tree with water dropping from trees during a dry season is a sign of the onset of short-rainy seasons. Based on astrological indicators, Radeny *et al.* (2019) found that when the moon is surrounded by heavy clouds, it predicts a good rainfall season, while frequent winds indicate that it will rain within a week. Therefore, the Climate Change, Agriculture, and Food Security (CCAFS) project, which was implemented for ten years, from 2011 to 2019, by the University of Leeds and the Consultative Group for International Agriculture Research (CGIAR) Programme in collaboration with Selian Agricultural Research Institute and Lushoto District Council, prioritized to farmers the use of indigenous weather forecast services to enable them to cope with seasonal weather conditions and adapt to climate change. Indigenous weather information was supposed to be triangulated with scientific weather forecasts disseminated by the Tanzania Meteorological Authority (AFRICAP, 2019).

Indigenous weather forecasting provides information and insights essential for successful adaptation to climate change at the local level (Chisadza et al., 2013). Studies that compared knowledge of indigenous weather forecasting and scientific weather forecast services reported similarities between the two (Zuma-Netshiukhwi et al., 2013; Chisadza et al., 2013). However, innovation characteristics such as perceived relative advantage, compatibility, complexity, observability, and trialability can affect sustained adoption of innovation (Muyiramye, 2020; Nyadzi et al., 2020). If there is no relative advantage and technology is complex to use, farmers are not likely to adopt and continue using CSA technologies. To this study, sustained adoption refers to a continuous use of indigenous weather forecast services after phasing out of the CCAFS project in the West Usambara Mountains. Denial of sustaining adoption of indigenous weather forecasts, particularly in rural areas where scientific weather information services are hardly accessible due to a lack of relative advantage and it is difficult to use the technology can result in low crop

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productivity due to climate change. Therefore, this study assessed the effects of perceived relative advantage and complexity on sustained adoption of indigenous weather forecast services in the West Usambara Mountains after phasing out of the CCAFS project.

1.1 Statement of the Problem

Farmers in the West Usambara Mountains are facing challenges posed by climate change such as unpredictable rainfall, increased temperature, floods in valley bottoms and lowlands, and outbreaks of pests and diseases that reduce the productivity of crops such as maize, beans, vegetables, and fruits. A lack of understanding of farmers' perceptions of innovation characteristics regarding indigenous weather forecast services can limit a long-term use of indigenous weather information in predicting and interpreting weather conditions. For instance, crop production is at higher risk if farmers don't understand seasonal weather. Awareness of climatic and weather conditions helps farmers cope with climate variability and adapt to climate change. Indigenous weather forecasts promoted by the CCAFS project are essential in enhancing the predictability and precision of weather forecasting, especially in rural areas like the West Usambara Mountains, where access to scientific weather forecasting is still poor since most farmers lack access to mass media such as televisions and radios; instead, the majority have access to indigenous weather forecasts (Radeny et al., 2019; Elia et al., 2014). Additionally, scientific weather forecasting is not specific to a small area with a distinctive microclimate since its information is widely generalized (Muyiramye, 2020; Johnstone et al., 2022). Unfortunately, there is still inadequate information regarding a system that synergies the accuracy of modern weather services with the resilience of indigenous weather forecasting systems (Kalanda-Joshua et al., 2011). In the West Usambara Mountains, little has been studied on indigenous weather forecast services with a focus on the interpretation of biotic and astronomical indicators used by farmers in forecasting seasonal weather to reduce agricultural risks and losses posed by climate change (Radeny et al., 2019).

Lack of understanding regarding farmers' perceptions of weather forecast services increases the risks posed by climate change in crop production. Therefore, this study assessed the effects of perceived relative advantage and complexity on sustained adoption of indigenous weather forecasts in the West Usambara Mountains, particularly after phasing out of the CCAFS project. The study will assist decision-making and planning post-CCAFS project interventions that can integrate farmers' perceptions of innovation characteristics to enhance long-term adoption of indigenous weather forecast services. Availability and precise indigenous weather forecasts, especially when integrated with scientific weather forecasts, will enable many farmers to use weather information to reduce the risks posed by climate change and ultimately increase crop productivity. The study findings contribute to the implementation of National Agricultural Policy 2013, Agricultural Sector Development Strategy II (ASDS II) 2015/16-2024/25, Tanzania Climate Smart Agriculture Programme 2015-2025, and National Climate Change Response Strategy 2021-2026.

1.2 Research Objectives

This study aimed;

i. To determine sustained adoption of indigenous weather forecast services after phasing out the CCAFS project.
ii. To evaluate farmers' access to indigenous weather information services.
iii. To examine the effects of perceived relative advantage and complexity on sustained adoption of indigenous weather forecast services after phasing out of the CCAFS project.

II. LITERATURE REVIEW

2.1 Theoretical Review

The diffusion of innovation theory served as the foundation for the study. Pioneered by Everett Rogers in 1962, this is a widely applied theory in explaining adoption and diffusion of technologies in different disciplines such as agriculture (Ogada et al., 2020; Mardiana and Kembauw, 2021). According to Rogers (2003), adoption refers to an individual's decision to make full use of an innovation as the best course of action available, whereas rejection is a decision not to use innovation. Innovation or technology refers to an idea, practice, device, or method that is new to an individual or unit of adoption, even if it has existed for some time. Innovation is important because it reduces uncertainty and helps to achieve an outcome or impact of intervention. In the adoption process, an individual decides either to continue or discontinue adoption after periods of repeated use of innovation. According to Oldenburg and Glanz (2008), sustained adoption refers to a continuous use of technology after the end of the diffusion project. The theory posits that interpersonal communication channels, including peer-to-peer information exchange, experts, and meetings, can disseminate innovations like indigenous weather forecasts.

Various factors, such as individuals' perceptions of relative advantage, compatibility, complexity, trialability, and observability, can influence the adoption of technology (Rogers, 2003). This study used the Diffusion of

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Innovation Theory to assess the effects of perceived relative advantage and complexity on sustained adoption of indigenous weather forecast services. According to Rogers (2003) and Dearing (2009), relative advantage refers to the perceived superiority of an innovation over its replacement in terms of economic profitability, low initial cost, and reduced discomfort and effort, while complexity refers to the perceived difficulty of understanding and using the innovation. This study used the Diffusion of Innovation Theory to explain what it means for an innovation to be adopted over time and how people see its features, especially its relative advantage and complexity. So, this study looked at how perceived relative advantage and complexity affect the continued use of indigenous weather forecast services in the West Usambara Mountains, especially after the CCAFS project ended.

2.2 Empirical Review

Indigenous weather forecasts provide seasonal weather information by interpreting biotic indicators such as insects, birds, and trees, as well as abiotic indicators such as clouds, stars, and wind. This type of weather forecasting is essential to farmers, especially in rural areas where scientific weather forecasts are hard to reach farmers or when meteorological information is widely generalized (Elia et al., 2014; Mofongoya et al., 2021). Often, elders are highly experienced in interpreting signs and behaviour of biotic and abiotic indicators and passing indigenous knowledge to youths (Gwenzi et al., 2016). Previous studies explained indigenous weather forecasting indicators and the relationship between farmers' perceptions of relative advantage and complexity and sustained adoption of indigenous weather forecast services after the end of diffusion interventions (Rogers, 2003; Muyiramye, 2020; Mbilinyi, 2020). Relationships between farmers' perceptions of relative advantage and complexity and sustained adoption of indigenous weather forecast services were explained by several empirical studies conducted in different geographical locations.

Muyiramye (2020) assessed perceived relative advantage and complexity among farmers in the northwest province, particularly in the Nyabihu and Musanze Districts of Rwanda. Data collection was conducted through a questionnaire survey, interviews, and focus group discussions. Quantitative data were analyzed descriptively, while thematic analysis used qualitative data. Results show that farmers are using indigenous weather forecasts through interpretation of behaviour and patterns from wind, sky, domesticated animals, insects, and human body feelings. Perceived complexity constrains adoption and continuous use of indigenous weather forecasts, especially for most youths since they find them difficult to use and understand. Relative advantage motivated farmers to adopt and continue using indigenous weather forecast services because predictions and interpretation are specific to their areas, hence enabling them to decide about agricultural activities, including the type of crop to grow.

Elia et al. (2014) used the Diffusion of Innovation Theory to determine the use of indigenous weather forecasting indicators and farmers' perceptions of relative advantage in using indigenous knowledge of weather forecasts in Semi-Arid Regions of Central Tanzania after the implementation of the Climate Change Adaptation in Africa (CCAA) project. Data were collected through a questionnaire survey, interviews, and focus group discussions. Quantitative data were analyzed through descriptive analysis, while content analysis was conducted using qualitative data collected through focus group discussions and interviews. Results found that farmers sustained adoption of indigenous weather forecast services after realizing the relative advantage of using them for making decisions regarding agricultural activities. Indigenous weather information is easily accessible to farmers and specific to their localities. Farmers use behaviour and patterns of biotic indicators such as birds, animals, and insects and abiotic indicators such as stars and clouds for prediction of seasonal weather, whereby elders disseminate indigenous weather information.

In Northern Ghana, Nyadzi et al. (2020) assessed the reliability and complexity of continuous adoption of indigenous weather forecasts using purposive sampling of over 45 aged farmers with experience in indigenous weather forecasting. The study used descriptive analysis to analyze quantitative data, while content analysis was used for qualitative data. Results showed that some farmers perceived the complexity of using biotic indicators such as ducks, frogs, butterflies, and birds and abiotic indicators such as clouds, moon, wind, and sun in interpreting seasonal weather since these indicators are constrained by the precision of predictability.

Gwenzi et al. (2016) studied the use of indigenous knowledge by farmers in Guruve District, north-eastern Zimbabwe, for short- and long-range rainfall prediction. Data were collected using household interviews, focus group discussions, and key informant interviews. Data were analyzed by using descriptive statistical analysis and content analysis. Results revealed that 80% of farmers used at least one form of indigenous weather forecasting indicators such as trees, birds, insects, and atmospheric phenomena. Farmers perceived that there was a relative advantage in using indigenous weather information since it contributes to increasing crop productivity under climate change. Elderly groups were the main channel of communication of indigenous weather information. Youths perceived a complexity in understanding and using indigenous weather forecasting indicators.

In Kondoa District, Tanzania, Mbilinyi, D. (2020) assessed the role played by indigenous weather forecasts for agricultural adaptation to climate variability. The study used a cross-sectional design to collect data from 188

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farmers through a structured questionnaire and key informant interviews. Quantitative data were analyzed using descriptive statistical analysis, while thematic analysis was conducted for qualitative data. Results show that 61% of farmers sustained adoption of indigenous weather information, which was disseminated through elderly groups and village reports. Indicators used for interpretation of seasonal weather were such as cattle, clouds, thunder, and body feelings of human beings. Farmers realized that there was a relative advantage in the adoption of indigenous weather forecast services, which helps them minimize or avoid risks of crop losses because such information is readily available within their areas.

Despite the above studies, none of them provided clear empirical explanations regarding the effects of farmers' perceptions of relative advantage and complexity on sustained adoption of indigenous weather forecast services after phasing out of the interventions using econometric models. Thus, unlike the above studies, this study used a binary logistic regression model to examine the effects of perceived relative advantage and complexity on sustained adoption of indigenous weather forecast services in the West Usambara Mountains, Tanzania, after ending the CCAFS project. Additionally, this study was conducted in the study area since factors affecting adoption of innovation are area-specific due to differences in farmers' perceptions, attitudes, preferences, socio-economic positions, and landscape (Shuaibu et al., 2014). From the empirical review, this study adapted variables and methods of data collection to address the study objectives.

III. METHODOLOGY

3.1 Description of the Study Area

This study was conducted in the West Usambara Mountains, particularly in Lushoto District, Tanga Region, Tanzania. This was an area where the CCAFS project promoted adoption of CSA technologies, including the integration of indigenous weather forecast services with scientific weather information services. The study area is located between latitudes 4^{0}05' and 5^{0}00' and longitudes 38^{0}05' and 38^{0}40' with altitudes ranging from 600m to 2300m (Minderhoud, 2011). A cross-sectional study design that employed both qualitative and quantitative approaches was used to collect data from the study area at a single point in time. The main crops grown in the study area include vegetables (such as tomatoes, cabbages, and carrots), Irish potatoes, beans, and maize. The reason for the selection of the study area was associated with the negative effects of climate change on crop production, which contributed to reducing yields of maize, beans, Irish potatoes, and vegetables, especially on farms located in uplands and valley bottoms. Additionally, the study area was selected because the CCAFS project helped farmers to respond to the negative effects of climate change in crop production through dissemination and promotion of adoption of CSA technologies, including indigenous weather information services in integration with scientific weather forecast services for 10 years from 2011 to 2029.

3.2 Sample Size and Sampling Procedures

The sample size was estimated by using a hypergeometric formula. This formula provides a statistically realistic sample size from a small population (Busbee, 2017).

$$n = \frac{Z^2 Npq}{e^2(N-1) + Z^2 pq}$$

Where; n = a sample size; N = survey population; p and q are population proportions (If they are not known, each set at 0.5); Z = is the value that specifies the level of confidence at 95% which is set at 1.96; and e sets the accuracy of the sample proportions of plus or minus 3% (or 0.03).

Then;

$$n = \frac{1.96^2 \text{ x } 140 \text{ x } 0.5 \text{ x } 0.5}{0.03^2(140-1) + (1.96^2 \text{ x } 0.5 \text{ x } 0.5)} = 124$$

Therefore, the sample size used in this study was 124 farming households which is equivalent to 88.6% of the survey population. The study sample was selected by using simple random sampling method from 140 farming households which received interventions during the CCAFS project. In this study, household heads represented their farming households.

3.3 Methods of Data Collection

The study used three methods for data collection, including household questionnaire surveys, interviews, and focus group discussions (FGD). During the survey, a structured questionnaire was used as an instrument to collect quantitative data from respondents. Key informant interviews were conducted for each of the three participants: the District Agriculture, Irrigation, and Cooperative Officer and two Agriculture Extension Officers who participated in the phased-out CCAFS project. Seven FGDs comprised males and females, elders, and young people and were

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conducted in seven villages, including Boheloi, Yamba, Gare, Kwang'wenda, Mbuzii, Milungui, and Masange. These villages were the targets of the CCAFS project. Hence, this study used mixed methods of data collection to enhance the validity and credibility of data.

3.4 Data Analysis

Quantitative data collected through a questionnaire were coded in IBM SPSS version 20 and then analyzed by using descriptive statistical analysis and binary logistic regression. Sustained adoption was a dependent variable measured using binary indicators; coded 1 if farmer sustained adoption of indigenous weather information services after phasing out of the CCAFS project; and 0 if not sustained adoption. Independent variables included two dimensions of relative advantage and two dimensions of complexity perceived by farmers as shown in Table 1. The binary logistic regression model is shown below:

$$\ln\left[\frac{P}{1-P}\right] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon_i$$

Whereby;

P= Probability of sustained adoption of indigenous weather information services after phasing out of the CCAFS project; 1 if farmer sustained adoption; and 0 if not sustained adoption (Table 1).

X_1, X_2, X_3 and X_4= Independent variables explained in Table 1.

β_1, β_2, β_3 and β_4 are coefficient of X_1, X_2, X_3 and X_4 respectively.

β_0 = Constant and ε_i= Error term.

Thematic analysis was used for qualitative data collected from key informants and FGDs. The analysis of qualitative data generated in-depth information about the farmers' perceptions of the relative advantages and complexity of indigenous weather information services. Thematic analysis complemented the quantitative results by triangulation.

Table 1

Independent and Dependent Variables, and Measurements

Variable	Explanations/dimensions	Measurement	Effect sign
Dependent variable:			
Sustained adoption	Farmer continued using indigenous weather information services after phasing out the CCAFS project	1=If sustained adoption 0=Otherwise	
Independent variables:			
Perceived relative advantage	X1=Perceived relative advantage in increasing crop productivity (RA1)	1=If agreed 0=Otherwise	+
	X2=Perceived relative advantage in reducing costs (RA2)	1=If agreed 0=Otherwise	+
Perceived complexity	X3=Perceived complexity in using indigenous weather information services(COMPL1)	1=If agreed 0=Otherwise	-
	X4=Perceived complexity in understanding indigenous weather information services(COMPL1)	1=If agreed 0=Otherwise	-

IV. FINDINGS & DISCUSSIONS

4.1 Distribution of Respondents Based on Demographic Characteristics and Sustained Adoption of Indigenous Weather Forecast Services

In this study, 124 respondents, equivalent to 100%, filled out the questionnaire during the household survey. The study revealed that among the demographic attributes (sex, age, education, and land ownership) of respondents, sex had a significant association with sustained adoption of indigenous weather forecast services (chi-square = 5.163, $p = 0.023$), whereby more males continued using indigenous weather information for crop production than women (Table 2). The dominance of the patriarchal system in the study area favors males in access and control of agricultural technologies, including opportunities to get and use weather information services. This expressed a reason for higher sustained adoption of indigenous weather information services among males than females. Contrary to the study findings, Johnson et al. (2022) reported that sex of a farmer was not a significant factor in sustained adoption of indigenous weather forecast services in Chiredzi District, Zimbabwe, since there was no gender dominance in access to indigenous weather information, unlike the study area.

Based on the age of the household head, more elderly farmers (75.5%) sustained adoption of indigenous weather forecast services compared to other age groups. However, there was no significant association of adoption with age groups (Table 2). Getyengana et al. (2023) reported findings related to this study that the majority of adult

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farmers were using indigenous knowledge to reduce climate risks in agriculture, especially in integration with scientific weather information. Findings revealed by this study express that elders have long experience in indigenous practices. Their experience enabled them to become aware of and clearly understand the usefulness of indigenous weather forecasting in predicting seasonal weather and to be able to apply such information in farming activities to reduce the risks posed by climate change. Unlike the study findings, there was a significant positive relationship between the 46 and 49 age groups and sustainable adoption of indigenous weather forecasts in Chiredzi District, Zimbabwe, since many farmers belonging to such an age group continued using indigenous weather information for climate change adaptation in agriculture (Johnston et al., 2022). Moreover, the majority of farmers sustained adoption of indigenous weather forecast services irrespective of their differences in education levels and ownership of agricultural land (Table 2). In contrast, Getyengana et al. (2023) found that the majority of farmers with informal education were using indigenous knowledge to predict weather conditions that enable them to reduce risks posed by climate change in South Africa.

Table 2

Distribution of Respondents about Sustainability in Adoption of Indigenous Weather Forecast Services

Demographic variable	Category	Not sustained adoption (%)	Sustained adoption (%)	Chi-square (X^2)	p-value
Sex	Male	26.6	73.4	5.163*	0.023
	Female	46.7	53.3		
Age	20-39	30.8	69.2	4.328	0.115
	40-49	43.1	56.9		
	≥60	24.5	75.5		
Education	Non-formal	35.5	64.7	0.894	1.000
	Formal	33.6	66.4		
Land ownership	Owned	32.4	67.6	0.319	0.231
	Not owned	44.4	55.6		

*Significant at $p \leq 0.05$

4.2 Sustained Adoption of Indigenous Weather Forecast Services among Farming Households

The CCAFS project promoted adoption and continuous use of climate-smart agricultural technologies, including indigenous weather forecast services, before it was phased out in 2019. This study found that 66.1% of respondents sustained adoption of indigenous weather forecast services. Farmers rely on the interpretation of changes in behaviour and pattern of biotic indicators such as plants, birds, insects, and butterflies and abiotic indicators such as stars, clouds, and wind. Other farmers (33.9%) either not adopted indigenous weather information services or discontinued after phasing out of the CCAFS project. The focus group discussions expressed that indigenous weather information enables farmers to immediately decide about agricultural activities such as the type of seeds to use and a time suitable for farm preparations. This was possible since information given by indigenous weather forecasting is readily accessible and specific to the study area, unlike scientific weather forecasting. The findings of this study concur with Soropa et al. (2015), who reported that 67% of farmers were still using indigenous weather forecasts in Murehwa, Tsholotsho, and Chiredz District in Zimbabwe after promotion, which was done by the Community Technology Development Trust. The findings revealed by this study were also related to Gwenzi et al. (2016), who reported that 80% of farmers used indigenous weather forecasting services in Guruve District, north-eastern Zimbabwe. Similar findings were also reported by Mbilinyi (2020) that the majority of farmers (61%) continued adoption of indigenous weather forecast services in Kondoa District, Tanzania.

4.3 Farmers' Access to Indigenous Weather Information

Farmers obtain weather information from different channels of information (Table 3). Access to indigenous weather information disseminated was ranked as poor, moderate, and good based on farmers' perspectives regarding their easier to get such information from different pathways. The majority of respondents (48.8%) ranked moderate access to indigenous weather information disseminated by weather forecasting groups initiated by the CCAFS project (Table 3); many others had either somewhat or poor access to indigenous weather information disseminated by other weather forecasting groups apart from that initiated by the CCAFS project and local elders.

More farmers had good access to indigenous weather information disseminated by peer-to-peer farmers' exchange of information (66.7%) and elders (32.7%). Reliable and precise weather information enables farmers to decide on farming activities to cope with seasonal weather conditions. Farmers practicing related agricultural activities usually share information based on expertise and wide experience in interpreting and predicting weather conditions from biotic indicators such as varieties of plants and animals and abiotic indicators such as wind, stars, and clouds.

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Peer farmers can also exchange weather information received from weather forecasting groups and local elders. This study concurs with Gwenzi *et al.* (2016) and Mbilinyi (2020), who also reported that elders played a role in the dissemination of indigenous weather information in north-eastern Zimbabwe and Kondoa District, Tanzania, respectively.

Table 3

Access to Indigenous Weather Information from Interpersonal Communication Channels (n=124)

Communication pathways information	Poor (%)	Moderate (%)	Good (%)
Group initiated by the CCAFS project	39	48.8	12.2
Other weather forecasting groups	44.1	44.1	11.8
Elders	18.2	49.1	32.7
Peer-to-peer farmers	5.6	27.8	66.7

4.4 Effects of Perceived Relative Advantage and Complexity on Sustained Adoption of Indigenous Weather Information Services

4.4.1 Perceived Relative Advantage and Complexity of Indigenous Weather Forecast Services

The study used a five-point Likert scale to measure farmers' perceptions of the relative advantage and complexity of using indigenous weather forecasts in the study area based on farmers' responses to measurement items. The five measurement indicators of the scale were strongly disagree, disagree, neutral, agree, and strongly agree. Responses summated into three perspectives: disagree (for strongly disagree and disagree), neural, and agree (for agree and strongly agree), as shown in Table 4.

Table 4

Descriptive Statistics of Perceived Relative Advantage and Complexity of Indigenous Weather Forecast Services (n=124)

Variable	Dimension	Disagree (%)	Neutral (%)	Agree (%)
Relative advantage	Perceived increase in crop productivity.	38.7	8.9	52.5
	Perceived low costs of getting information.	38.7	7.3	54.0
Complexity	Perceived difficulty in using weather information.	52.4	6.5	41.1
	Perceived difficulties in understanding weather information.	43.6	8.9	47.5

In this study, relative advantage is the extent to which using indigenous weather forecasts is perceived as being better than not using them. Hence, farmers' perceptions of crop productivity and reduction of costs are important measurement dimensions of relative advantage. Based on perceived relative advantage in the study area, results show that majority of respondents perceived increased crop productivity (52.5%) and perceived low costs of getting indigenous weather information (54%) (Table 4). Related findings were reported by File and Nkamo (2023) that farmers in Ghana do not need money to obtain indigenous weather information since they can predict weather conditions through their local knowledge. Availability of precise weather information on time helped farmers to integrate indigenous weather forecast with scientific weather information in farming activities such as timing farm preparations and selection of the type of seeds to use to increase yields under climate change. Application of weather information from indigenous weather forecasts saves costs because dissemination of information doesn't require mass media such as radio, television and newspapers; instead, it is locally available from elders and peer farmers. Findings from FGDs revealed the relative advantage of using indigenous weather forecasts in which some varieties of plants and animals, and astronomical elements such as clouds, stars and wind have been used to interpret and predict seasonal weather conditions to inform decision-making about agricultural adaptation to climate change in the study area. Interpretation of signs and behaviour change of indigenous weather indicators enable farmers to understand possibilities of occurrence of rainfall, amount of rainfall, termination of rainfall and dryness. Moreover, results from FGDs revealed that farmers have been using indigenous weather forecasts to understand short-term weather conditions in integration with scientific weather forecasts provided by the Tanzania Meteorological Authority to enhance information availability and precision of prediction. During FGDs, one participant said;

> *"We also use indigenous weather forecasting since it predicts seasonal weather of our specific locations compared to scientific weather information which is widely generalized. The use of both weather forecasting methods is more important to farmers for enhancing reliability and precision of weather information."* (FGDs, Gare Village, June 2022).

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The evidence of usefulness of indigenous weather forecast in yield increase particularly when integrated with other improved technologies was expressed during FGDs. For instance, one of the members said;

> *"Nowadays, crop production faces many challenges associated with climate change apart from soil infertility. Farmers have been relying on the application of weather information services particularly indigenous knowledge of weather prediction which helps to increase yields especially vegetables and Irish potatoes which are highly vulnerable to short-term variability of weather conditions such as mist and fog and crop diseases."* (FGDs, Yamba Village, June 2022).

Perceptions of the complexity of indigenous weather forecasts were assessed using two dimensions; difficult use of weather information and difficult to understand weather information. The study shows that there were respondents who disagreed with statements and others who agreed (Table 4). Farmers who find it difficult to understand information from indigenous weather forecasts can also face difficulties in applying weather information in farming activities to reduce the risks posed climate change. Difficulties facing farmers in using indigenous weather information minimize the efficiency and effectiveness of indigenous weather information in reducing agricultural risks posed by climate change and seasonal weather variability. The FGDs revealed that most farmers who didn't understand weather information related to indigenous weather forecasts were youths because they are new to farming activities and had not been explained enough by their parents or elders about indigenous weather forecasts during their childhood. One among the members of FGDs members said that;

> *"Most elders don't pass indigenous knowledge of weather forecasting to young generations partly due to lack of readiness among youths while some of them ignore traditional knowledge because they are educated."* (FGDs, Milungui Village, June 2022).

The findings revealed by this study concur with Nyadzi *et al.* (2021) who noted that the application of indigenous weather forecasts requires a long-term learning process whereby the age and experience of the person matter.

4.4.2 Analysis of the Effects of Perceived Relative Advantage and Complexity on Sustained Adoption of Indigenous Weather Forecast Services

Analysis of the effects of perceived relative advantage and complexity on sustained adoption of indigenous weather forecast services was done through binary logistic regression. The model fitness revealed by Omnibus Tests of Model Coefficients confirmed an overall significance of the model by significant p-value. The p-value shown in Table 4 suggests that at least one predictor (dependent variable) variable is significantly associated with the binary outcome. In this study, the binary outcome was sustained adoption of indigenous weather forecast services. Predictor variables were dimensions of perceived relative advantage and complexity of weather indigenous weather information services.

Table 5

Omnibus Tests of Model Coefficients

Model	Chi-square	df	p-value
Step	115.758	4	0.000
Block	115.758	4	0.000
Model	115.758	4	0.000

Cox and Snell R^2 and Negelkerke R^2 are regarded as pseudo R^2 values. The higher values of Cox and Snell R^2 and Negelkerke R^2 justify better model fitness. From Table 6, the R^2 values for Cox and Snell R^2 were 60.7% and for Negelkerke R^2 was 84% which are higher enough for the model to explain the binary outcome. The logistic regression analysis revealed that perceived relative advantage in increased crop productivity had positive significant effect on sustained adoption of indigenous weather forecast services (β=3.777, p=0.003) particularly after three years since the CCAFS project was phased out in 2019 (Table 5). One unit increase in perceived relative advantage in increased crop productivity increases sustained adoption of indigenous weather forecast services by 43.702 odds (Exp β). Hence, increasing crop productivity due to the application of weather information from indigenous weather forecast services integrated with other Climate-Smart Agricultural technologies increases the likelihood of sustained adoption of indigenous weather forecast services particularly after phasing out of the CCAFS project. This study concurs with other studies which demonstrated relative advantage of using indigenous weather forecasts in increasing yields (Elia et al., 2014, Mofongoya et al., 2021; Johnston et al., 2022). Most farmers who perceived an increase in crop productivity after using indigenous weather information managed to continue using indigenous weather forecast services to reduce the risk of climate change especially in crop production. Some FGDs confirmed that farmers increased yields of cereals and vegetables since they usually use indigenous weather information integrated with scientific weather forecasting. Further, FGDs availed that indigenous weather information is locally available from elders and

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knowledgeable peer farmers with experience in interpreting natural indicators of indigenous weather forecasts. One participant of FGDs said that;

> *"Since indigenous weather information is more reliable and accessible to farmers in time, it helps to make decisions about farm preparations and the right seed choice based on weather. Understanding seasonal weather enables farmers to increase crop production by minimization risks and yield losses due to climate change-related adversities such as seasonal droughts, intensive rains and outbreaks of pests and diseases.*" (FGDs, Kwang'wenda Village, June 2022).

Results regarding the effect of perceived relative advantage on sustained adoption of indigenous weather forecast services concur with Diffusion of Innovation Theory which assert that perceived relative advantage are positively related to sustained adoption of innovation.

Perceived complexity of difficult-to-use indigenous weather information in deciding farming activities had a significant negative effect on sustained adoption of indigenous weather forecast services (β = -3.577, p = 0.008), as shown in Table 6. One unit increase in complexity of difficult-to-use indigenous weather information decreases the chances of sustained adoption of indigenous weather forecast services by 0.028 odds (Exp β). This expresses that the likelihood of sustained adoption of indigenous weather forecast services among farmers decreases with the complexity of using indigenous weather information. Hence, most farmers who perceived difficulties in using indigenous weather information abandoned indigenous weather information services in the study area. From the key informant interviews, it was found that some farmers abandoned the use of indigenous weather information services, especially after phasing out of the CCAFS project, which was promoting this practice after facing difficulties to use. Youths lacking long-term learning experience of indigenous knowledge find it difficult to use indigenous weather information through interpretations of biotic indicators such as birds, mammals, trees, and insects and abiotic indicators such as stars, cloud cover, and wind. Related findings were reported by Mofongoya et al. (2021), who found that there was poor transfer of indigenous knowledge of weather forecasting to youths in Bikita District, Zimbabwe, partly due to modern education and religious beliefs that regard the use of indigenous weather forecasts as witchcraft. Gwenzi and Mushonjowa (2015) noted that disappearance or difficulty in finding indigenous weather forecast indicators is a challenge that constrained many youths to adopt and continue using indigenous weather information for agricultural adaptation to climate change. Related findings revealed by Nyadzi et al. (2020) expressed that some farmers face difficulties in interpreting signs and behaviour of indigenous indicators used by farmers in predicting seasonal weather in Northern Ghana. The findings revealed by this study regarding the effect of perceived complexity on sustained adoption of indigenous weather forecast services approve the Diffusion of Innovation Theory, which suggests that perceived complexity is positively related to sustained adoption of innovation.

Table 6

Effects of Perceived Relative Advantage and Complexity on Sustained Adoption of Indigenous Weather Forecast Services (n=124)

Variable	Dimension	β	S.E.	Wald	Sig.	Exp(β)	95% C.I. for Exp(β)	
							Lower	Upper
	Constant	2.407	1.066	5.095	0.024	11.095		
Relative advantage	RA1	3.777	1.276	8.760**	0.003	43.702	3.58	533.17
	RA2	0.354	1.190	0.088	0.766	1.425	0.14	14.66
Complexity	COMPL1	-3.577	1.356	6.960**	0.008	0.028	0.01	0.39
	COMPL2	-1.422	1.569	0.821	0.365	0.241	0.01	5.22

Cox & Snell R^2 = 60.7%
Negelkerke R^2 = 84%
**Significant at p≤0.01
RA1=perceived increase in crop productivity; RA2=perceived low cost; COMPL1=perceived difficult to use; COMPL2= perceived difficult to understand

V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusions

Indigenous weather forecast services are essential especially in the West Usambara Mountains where precision of scientific weather information is often challenged by a wide coverage of prediction. Integrating indigenous weather forecasts with scientific weather information increases reliability and precision of weather information required by rural farmers. Utilizing peer-to-peer farmers' exchange of information was the main communication channel used for dissemination of indigenous weather information although there were other communication pathways such as local elders and weather forecasting groups. Perceived relative advantage in

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increasing crop productivity and perceived complexity in using indigenous weather information are important innovation characteristics increasing and constraining the likelihood of sustained adoption of indigenous weather information services respectively particularly after phasing out of the CCAFS project in the West Usambara Mountains. Propositions explained by the Diffusion of Innovation Theory regarding the effects of characteristics of innovation particularly perceived relative advantage and perceived complexity on sustained adoption of innovation have been confirmed by the findings. The theory approved the theory that farmers' perceptions of relative advantage promoted sustained adoption of indigenous weather forecast services in the study area while complexity discouraged sustained adoption.

5.2 Recommendations

It is recommended that policymakers and extension workers provide effective mechanisms that can simplify the transfer and exchange of indigenous knowledge of weather forecasting among farmers to make sure that youths also understand and able to apply indigenous weather information in agricultural adaptation to climate change. Sharing information and knowledge among farmers regardless of their age groups will enhance long-term adoption of indigenous weather forecast services and improve agricultural productivity. Extension workers should apply an evidence-based performance approach such as using model farmers and demonstration farms to enhance knowledge and make easier to farmers in using indigenous weather forecasts to reduce climate-related agricultural risks and losses. The study findings are useful in reviewing post-CCAFS project interventions and designing other sustainable agricultural projects resilient to climate change that integrate indigenous weather forecasting with scientific weather information services. There will be a reduction of both climate risks and yield losses if farmers find simplicity (not complex) and relative advantage in adopting indigenous weather forecast services especially if used together with information from scientific weather and climate information available within their areas.

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