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Weather and climate information needs of small-scale farming and fishing communities in western Kenya for enhanced adaptive potential to climate change

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Abstract**—** Hydro-climatic variability owing to climate change is a major driver of vulnerability among subsistence rural farmers in Kenya. Vulnerability is exacerbated by a lack of reliable weather and climate information necessary to support adaptation to more resilient farming practices. In the form that it is currently delivered, weather and climate information does not support the operational decisions that farmers and fishers make such as timing of land preparation, planting time, type of seed or likelihood of severe weather. This paper presents the results of an approach for eliciting perspectives from farmers and fishers on the weather and climate information products they need to support operational decisions. The specific objectives of the study were to: quantify the capacity of the agricultural and fishing communities to use existing weather and climate information; evaluate the service improvements delivered to farmers and; develop and test community education and awareness tools designed to help farmers and fishers make better decisions that reduce risks to their lives and livelihoods. The study was conducted in Rarieda constituency between August 2011 and December 2011. 401 farmers and 34 fishers were interviewed coupled with interactive focus group discussions with expert farmers and fishers. Results show that approximately 92% of farmers receive weather and climate information, mainly through radios and local administration, yet only 14% find the information useful in their operational decisions. Conversely, fishermen reported that there was no weather and climate information directly targeting them. Long term forecasts significantly influenced nearly all operation decisions which accounted for about 35.9% of the total variability in land preparation, 34.3% choice of seeds, 2.6% planting time and 36.1% in disaster management whereas daily forecasts had no statistical significance ($p > 0.05$) on any of the operations. 89% of the respondents were willing to pay for weather and climate information services though this was highly correlated with the wealth of an individual (X^2 $(4, N = 401) = 23.521, p < 0.001$). The study concludes that the weather information currently received by farmers is inadequate and service improvements need to be enhanced for optimal use of the available weather forecast for informed livelihood operational decisions.

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I. Introduction

One of the great challenges of weather and climate science is estimating the probability of the occurrence, severity and duration of an extreme event, as well when and where the event will take place [1]. This uncertainty poses major threats to small scale farming and fishing communities in sub-Saharan Africa, especially in East Africa where about 80% of the population depend on rain-fed agriculture and over 15% on aquatic resources along the Lake Victoria basin [2] as their main sources of livelihood.

The harsh effects of climate change have continued to exacerbate enormous difficulties among the poor households who are risk averse, leaving them more vulnerable and food insecure in many months of the year. A sure knowledge base from systematic observation and forecasting services is therefore essential to monitor climate; detect and attribute climatic change; improve the understanding of the dynamics of the climate system and its natural variability; provide input for climate models; and thus plan adaptation options [3]. In order to help meet these challenges, more investment in disaster risk reduction is needed, including building the capacity to anticipate risks and as well as provision of relevant and accurate weather and climate information services as an early warning strategy [4]. Skilful seasonal climate forecasts can also help not only to reduce climatic uncertainty, but also reduce livelihood risk to farmers and fishers only if the uncertainty associated with the forecast is accurately communicated, understood and integrated into the decision process [5].

This research was therefore conducted to quantify the capacity of the agricultural and fishing communities in Rarieda District of Western Kenya, to use existing weather and climate information; evaluate the service improvements delivered to farmers and; develop and test community education and awareness tools designed to help farmers and fishers make better decisions that reduce risks to their lives and livelihoods.

The main goal of this study was to enhance the adaptive capacity and increase resilience of small-scale farming and fishing communities to climate-induced vulnerability.

II. Research Design and Methodology

a) Research Site

This study was conducted in Rarieda District in Siaya County of Western Kenya. The district lies approximately 57 Km to the West of Kisumu and borders Bondo district to the north; Kisumu West district to the East; and Homa-Bay and Suba districts to the Southeast and the South respectively across the Winam gulf [6] (figure 1).

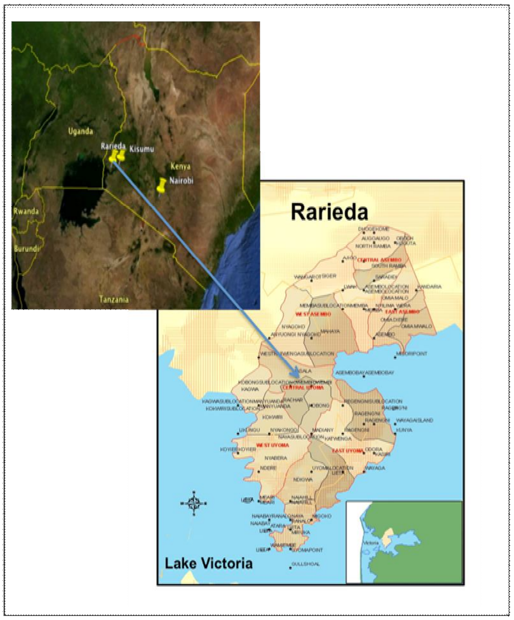

Fig. 1 Map showing location of Rarieda district in the western region of Kenya.

b) Research Design

Two sets of questionnaires were developed to gather information on the weather and climate information needs of the small scale farming and fishing communities. Some of the key variables encapsulated in the questionnaires were: demographic information of the respondents; the weather and climate information they currently receive; the agronomic and fishing decisions they make based on the information received; the information they wish to receive, their preferred media for such information and; their willingness to pay for weather and climate information services amongst others.

Before the execution of the survey, the questionnaires were pretested on a sample size of convenience on both groups (farmers and fishermen) to determine their suitability for the study. A number of changes were made thereafter to ensure that the questions were simple, relevant and clear to the main respondents with no ambiguity. The enumerators were adequately trained on how to gather information from the respondents to minimize chances of occurrence of non sampling errors. Also, since the questionnaire was designed in English and interviews were to be conducted in *Luo*, which is the local language, researchers and enumerators went through each question on the questionnaires together and agreed on the best possible vernacular translation for each question.

c) Data Collection

The questionnaires were administered to randomly selected households across all the 23 sub locations of Rarieda District irrespective of their occupation, gender, education nor age at an inter-house distance of at least 500m. All the households surveyed were mapped using a hand-held GPS device, e-Trex series, Garmin model for ease of traceability during the next visit and for spatial analyses.

The sample size was arrived at using the data of Kenya Population and Housing Census of 2009 which revealed that the 23 sub-locations had a total number of 31, 3000 households. Using this information, a representative number of households were drawn across all the sub locations using the following formula:

(Number of households per location/Total number of households in the 23 sub locations) X proposed sample size.

A total of 401 farm households and 34 fishing households were interviewed during the survey totalling up to 435 respondents. In addition to the questionnaires, 16 individual expert discussions and two large focus group discussions (FGDs) were conducted with farmers whereas 6 individual expert discussions and 3 FGDs were held with the fishermen.

d) Data Management and Analysis

The data collected during the survey process was captured in CS Pro software. The data entry interface in the software (CS Pro) was made to look similar as the questionnaire in hard copy with programmed logical checks and validation rules to minimize chances of error occurrence and also save time in data entry process. Double checking of the data was performed to ensure that it was error free and fit for analysis. The data was then exported to SPSS software, version 17 for windows for analyses.

Some of the exploratory analyses performed on key variables were; frequencies of demographic features of the households surveyed, multiple response analyses to determine the kinds of weather and climate information the farmers and fishers currently receive, the sources of information, assets owned across different households amongst others. Asset index was used as a proxy wealth indicator and was computed by summing up the assets owned under communication, mobility and production groups. The categories were recorded as follows; 0=no assets (basic level); 1=1-3 assets (intermediate level) and; 2=4 or more assets (high level). For the categorical variables, i.e. amount an individual was willing to pay for weather and climate information services, we chose to model the outcomes as binary, using ordinal logistic regression analysis against predictor variables (education level, household size, number of years spent in the farming, land size and asset index). Spearman's correlation test was performed within the predictor variables and those that had high variance inflation factors were omitted as they were considered redundant in the model.

In logistic regression analysis, the probability of an event occurring is estimated by:

$P(event) = 1/(1+e-(B_0 + B_1x_1 + B_2x_2 + \dots))$, where B_n represent coefficients assigned to each variable (x_i) in the model.

Because most of the variables were categorical in this dataset, each was assigned a set of "dummy variables" that can take on a value of one or zero, indicating membership or non membership in each category. The probability that each coefficient equals zero was tested using Wald statistic (the square of the ratio of the estimate to its standard error), which has a chi-square distribution. In further extrapolation of the data, the various forecasts i.e. daily forecast, forecast of the start and cessation of rains and forecasts of drought and other extreme events were further modelled through a multivariate Probit model procedure at 95 % confidence level to determine which forecasts had a magnitude influence on the farmers' day to day operation decisions and the variance components (coefficients of determination) of each of the predictor variables were estimated using Cox and Snell pseudo R squared. In the model, other factors like education level of the respondent, age, numbers of years spent on farming and family size were added as covariates.

The farm household survey results are presented in form of tables, bar graphs and pie charts. The statistically small number of fishermen surveyed was not sufficient for reasonable quantitative analysis therefore only a summary of responses from the focus group discussions with the fishermen are presented.

III. Results

a) *Demographic Information*

The minimum and maximum ages of the respondents interviewed were 14 and 85 years respectively with the mean average age being 43 years. The household sizes comprised of a minimum number of 1 and a maximum of 18 individuals with a mean of 5. Land holding size per household ranges between 0.2 acres and 20.0 acres with a mean of 2.88+/-2.62 (SD) acres. Over 80% of households interviewed had spent more than 10 years in farming. 71% of the fishers interviewed had been in the business for more than 10 years.

60% of the household heads had basic primary education; 21% secondary education; 9.4% post secondary education and 9.7% no education at all. 84% of the households owned radios, 80% owned a cell phone and 20% owned a television set. 70% of the households had access to financial services through M-Pesa (mobile money), while 57% participated in village savings and credit schemes. 70% of households owned bicycles, 10 % motorcycle and car 0.5%. Other assets owned by households were cattle (70%), poultry (82%), goats (63%) and sheep (45%). The main source of water was tap water (57%). Other sources were dam/pond (34%), shallow well (27%) and borehole (12%).

b) *Weather and Climate Information Received*

Approximately 92% of farmers said they receive weather and climate information and only 8% did not receive such information. The weather information currently being received comprised of: daily forecasts (20.9%), forecasts of the start and cessation of rains (21%), forecast of extreme events i.e. drought, heavy rains etc (19%) and forecast of pest and disease outbreak (17.7%). 56% of households received weather and climate information through radio. The second most popular source (26%) was public meetings (*baraazas*) convened by the provincial administration authorities.

In 26% percent of the households women were the primary recipients of the information while 13% indicated men as the main recipient. 61% of the households reported that they received the information as a family unit. 74% of households rated the information somewhat useful to operational decisions relevant to agriculture. However, households reported that they did not trust the daily forecast and that they did not find the geographic coverage relevant to the locality. The fishers did not receive any information relevant to their operations and felt it was more relevant to famers.

c) *Influence of Information on Operational Decisions*

The weather and climate information influenced several operational decisions at the farm household level. 12.4% of the households indicated that the information influenced their decisions on land preparation. 12% of the respondents reported that the information they received influenced planting time; 8.9% of the households indicated that the information was important for making risk management, especially with regard livestock type and stocking density and; 11.6% of the households reported that information they received was useful for pest and disease management.

Mid-term and long-term forecasts i.e. forecast of; on set and cessation of rains, including severe weather forecast and pest and disease outbreaks had the greatest influence on operational decision making at the household level (see Table 1). Forecast of onset and cessation of rains explained 41% of the variability in land preparation and planting time among the households. Similarly, forecast of on-set of drought, pests and diseases rains explained 37.6% of the variability livestock herd size among households.

Table 1 Regression of farmers' operation decisions on the weather and climate forecasts they currently receive (N=401).

	Forecast of onset & cessation of rains				Forecast of drought, pest and dse. outbreak			
	Coef	Wald-Chisq	Pr	R^2	Coef	Wald-Chisq	Pr	R^2
Operation								

Land Prep	-8.196	20.175	.000*	.409	.663	5.466	.019*	.359
Seed Choice	-6.991	15.306	.000*	.386	.554	3.901	.004*	.343
Planting time	2.228	2.458	.117	.409	.717	6.403	.011*	.360
Weed control	.474	1.02	.749	.358	.629	4.950	.026*	.326
Water Mgt	.738	15.849	.000*	.360	1.074	4.402	.036*	.330
Disaster Mgt	17.996	5.71	.000*	.330	.660	5.583	.018*	.361
Livestock herd size	.191	0.14	.905	.345	.1.093	13.266	.000*	.376

***P values are significant at 95 % confidence level; Cumulative R squared for daily forecasts* (main information received by farmers) = .2745; (Adjusted R squared = .2743). Coefficients are from the final model (all main effects, but no interaction term).**

d) Weather and Climate Information Needs

Asked what kind of information they would like to receive, households indicated; on-set and cessation of rains (20.7%), drought forecast (20.1%) and pest & disease outbreak (19.6%). The fishermen were interested in short-term forecast of wind direction and movement of water currents. The respondents valued the information for their day to day operation decisions in terms of land preparation (12.4%), planting time (12%), pests & disease control (11.6%) and livestock herd density management (8.9%). Radio ranked highest as the preferred media (95.8%), while 63.8% indicated that they preferred to receive weather and climate information through officials of the provincial administration and 48.8% of the households preferred mobile phones (48.8%).

e) Willingness to Pay for Weather and Climate Information

89% of households interviewed indicated that they were willing to pay for weather and climate information services. Asset index, a composite proxy of household endowment had a significant effect (Table 2) on willingness to pay for weather and climate information services. Households belonging in the higher asset index category were more willing to pay for weather and climate information services than those in the lower category (X^2 (4, N = 401) = 23.521, p <0.001) (figure 2).

Table 2 Fitted ordinal logistic regression to determine specific factors influencing farmers' willingness to pay for weather and climate information services (N=401).

	Coef	Wald Chi-Square	df	Pr.
ACTIVITYYEARS	0.557	3.326	2	.190
FAMILYSIZE	-0.752	22.766	16	.120
LANDSIZE	-0.493	25.649	23	.318
ASSETINDEX	1.670	10.076	1	.002*
HHEAD	0.012	.002	1	.964

***P values significant at 95 % significance level. Only main effects have been included in the model, no interaction between terms.**

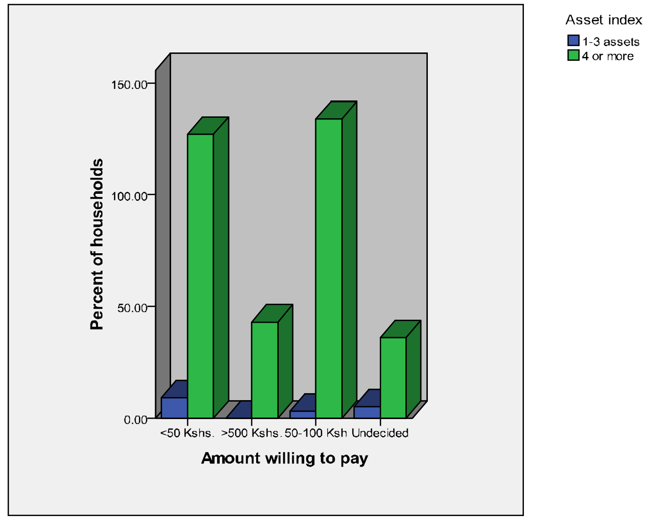

Fig 2: Willingness to pay for weather & climate information services by asset index

Other factors used as covariates like family size, land size, household head type and number of years spent on farming had no statistical significance on the farmers' willingness to pay for weather and climate information services (p> 0.05).

IV. Discussion

From the dataset analyzed, a wide range of farmers was interviewed; most of whom have been farming for more than ten years. The dataset also showed variance in age, household size, land size and assets. Most fishermen interviewed had also been fishing for over 10 years, some even as long as forty years. Not only does this varied demographic offer us invaluable insights into farmers' perception of climate change, needs and operational decisions, it also highlights the need for improved forecasts to take into account the heterogeneity of farmers and the need for a variety of forecast information and to tailor improved forecast information accordingly, a fact also noted by [5].

a) Weather and Climate Information Received

Although majority of farm households receive weather and climate information, i.e. mostly daily forecasts and forecasts of the start and cessation of rains, only a small proportion rated the information as somewhat useful to operational decisions relevant to agriculture. Conversely, all the fishers interviewed reported that the weather and climate information they received was not relevant to their operational decisions. Fishermen relied mostly on traditional methods and experiential understanding. The information is received primarily by women, which presents a problematic dynamic in a society where men monopolize decisions on management of agricultural resources. Women indicated that men would not listen or act on the forecast if they shared it with them.

Instead they relied on their experiential knowledge or consulted other male farmers.

Previous studies on the access, use and value of forecast information by smallholder farmers in developing countries generally reveal a high level of awareness and interest in using forecast information [7], therefore we postulate that the limited use and attribution of low utility value to forecast information is largely due to the fact that forecast information is not specific to the decision-making frame and needs of smallholder farmers.

Results from the FGDs that were conducted supported this hypothesis in that unreliability, uncertainty and mistrust of Kenya Meteorological Department (KMD) ranked high as reasons farmers gave for not using weather and climate information. Other studies have also noted a mistrust in weather and climate information and have expressed a need for forecast makers to focus on changing the farmer's perception of forecast accuracy (if not the actual accuracy itself) and perceived sense of control by making available more easy-to-understand forecasts through widely available and reliable media in a timely fashion [7]-[10].

Geographical specificity and skill (skill is a measure of the degree of correspondence between the forecast and the observation) of the seasonal forecast was a major factor. Farmers also took issues with seasonal forecast. They recalled numerous instances when the daily forecast "predicted" storms that did not materialize in their locality but did materialize in another a neighboring district. Consequently, the coarse scale of the forecast makes it difficult to apply locally. The credibility of the forecast, which in turn determines the amount of trust users place in the forecast, is partly determined by past skill and partly by forecast source reputation. There was therefore a dominant perception that making decisions based on forecast was risky, based on past failure of forecast to materialize. Farmers recalled receiving a La Nina warning, signifying drought, hence making decisions to reduce herd size. Then it turned out that the season was normal and they did not need to reduce herd size.

Trust was also affected by the way the forecast supports or contradicts local beliefs about the climate. Local beliefs are based on the notion that a deity controls weather and climate. Communities routinely offer prayers for rains, especially when there is a "prolonged" drought. Reference [10] noted that attitude had the most profound positive influence on use of climate forecasts in decision-making followed by norms, therefore a focus on changing both the farmers' and their societies' beliefs and values, and perceptions of weather and climate forecasts will in turn greatly affect their use and influence.

Improved credibility may therefore depend on improved forecasts. More importantly, modeling limitations and the chaotic nature of the atmosphere imply a probabilistic weather and climate forecast, as opposed to a deterministic forecast. What is needed therefore is communication that emphasizes the probabilistic nature of the forecast. Furthermore, credibility and trust may depend on better communication and more careful use of language, especially where translation from English into local languages is involved.

Other possible reasons that could also contribute to non optimal utilization of the available weather forecasts is the relatively low education levels amongst the small scale farmers interviewed, where a larger proportion possess only basic primary education. This according to [9] could be a barricading factor to farmers' ability to accurately introspect, estimate, and report the actual influence or weighting of forecasts upon their decisions. Similar studies by [11] also showed a strong correlation between the education level of the farmer and management operation decisions they make on a day to day basis.

b) Sources of Weather and Climate Information

More than half the respondents interviewed cited radio as the most common source of weather and climate information. At the secondary level, weather and climate information was received through local administration such as area chiefs and a limited number of people received such information via television, newspapers and other sources. This implies that improvements in use of weather and climate information have to target radio as the main source of weather and climate information. Radio still remains the most widely used medium in the rural areas; our study alone showed that more than two thirds of the respondents interviewed owned radios and over half of them regularly accessed weather and climate information through the radio. Additionally, results from our interviews and FGDs also revealed that most participants would prefer to receive weather and climate information over the radio. Another unlikely source of weather and climate information that emerged from our discussions was funerals. Respondents expressed weather and climate information that included rainfall information and choice of seeds would be announced by the area chief at funerals.

c) Improving Forecast Application

Most farmers interviewed for this study reported that in the past five years, they had made changes in crop production and livestock rearing as a result of weather and climate information received. Most of these changes were due to changing weather patterns such as increase in erratic rainfall, increase in overall rainfall, more frequent droughts and late/early onset of rains (rainfall patterns). Farmers interviewed reported that crops and animals most vulnerable to weather-related changes were maize and cows respectively, which are also the two dominant agricultural products in the region studied.

The high level of awareness and access to weather and climate information (92%) is strong evidence that there is a potential for reliable and timely information to positively influence agricultural decision-making at the farm household level. However, this potential remains largely untapped because as currently packaged and delivered, the weather and climate information does not cater to the needs of smallholder farmers. Benefits from such high awareness and access to weather and climate forecast can only be realized if the forecast is turned into information to support operational decision, especial minimizing risks associated with variability and uncertainty.

If farmers could receive and anticipate advance information about weather for the upcoming growing season and of this information could be delivered in a timely, accurate and reliable manner through widely available media with extended interaction between farmers and researchers then farmers would be able to use such information make better management decisions that would reduce their above-mentioned losses, minimize the use of costly farm inputs and as a result, maximize yield from their maize crops substantially [8], [12]-[13].

d) *Influence of Traditional Forecasting Methods*

Our FGDs showed that the common traditional methods of weather forecasting used by farmers included wind direction, cloud cover and presence or absence of algae in the lake surface to determine when the rains would come. Though this seemed mythical, it proved to be beneficial as farmers who used a hybrid of the two forecasts correctly maximized the use of the available seasonal rains. Reference [15] also showed that when both the traditional and scientific forecast information are available, farmers will apply both, but in the absence of meteorological forecasts, traditional forecasts together with previous experience remain the only basis for farm-level decisions pertaining to the coming season. Fishermen relied heavily on the use of traditional methods such as wind direction, moon sighting, croaking of frogs and cloud movement, even though some reported using general weather information to plan their operations i.e. rainy seasons usually means an increase in fish level, while the dry season has the opposite effect.

The enhancement of indigenous capacity is therefore a key to the empowerment of local communities and their effective participation in the development process [16]. Reference [17], laid emphasis on the importance of incorporation of scientific forecasts and the traditional knowledge of the farmer by arguing that this will strengthen the belief and trust of the farmers in using the available forecasts. People are better able to adopt new ideas when these can be seen in the context of existing practices therefore a system that integrates the two knowledge systems could potentially improve comprehension of uncertainties and limitations to application for farm management, as well as form a basis for fitting scientific forecasts into existing decision processes [15]-[18].

e) *Willingness to Pay for Weather and Climate Information*

A good proportion of farmers were ready to pay for weather information tailored to their needs as they understood the benefits that come with accurate and timely weather forecast on their operational decisions. On the other hand, fishermen were overwhelmingly opposed to paying for weather and climate information most likely because the information disseminated did not serve their needs at all.

There was a strong correlation between the asset index (composite proxy indicator of wealth) and the willingness to pay for weather and climate information services. This is documented by other studies, which noted that a farmer's financial abilities also affect that farmer's willingness to be influenced by weather forecasts [8] as well as association between willingness to pay for weather and climate information services and education status of an individual [19]. Households with better asset endowment have higher access to financial services and can use part of their wealth as collaterals to acquire soft loans with the banks, microfinance institutions or savings group to pay for climate and weather information services [19] without necessarily feeling the burden thus leaving poor households more vulnerable.

Therefore for effective adoption of improved weather and climate forecast information, such provision has to take into account the 'wealth' status of the household.

V. Conclusion

This study shows that there is a high level of community awareness on climate change; the risks posed by climate change and how it affects their livelihoods. In response to this awareness, most people are employing basic adaptation strategies to cope with the risks associated with climate change and variability. This study also shows that although weather and climate information is widely available, it is largely ignored by the users and gives three strong evidences to the non optimal use of weather and climate information services by the community. These include:

a) Existence of gaps between the information needed by farmers and that delivered to farmers (mismatch of information); In addition, fishermen are not receiving targeted weather and climate information that can significantly help them manage their operational decisions;
b) Lack of trust or miscommunication between users and providers and;
c) Lack of capacity at local scale to correctly interpret the available weather and climate information to address agriculture's needs.

With the existing gaps, we can conclude that improvements in weather and climate information have not necessarily translated into increased use by the community. We propose the following strategies to address farmers and fishers' weather and climate information needs in order to cope with the shocks poised by adverse climatic events:

a) Training of the community on how to interpret and accurately employ the use of available forecasts.
b) Multidisciplinary and multistage approach in the synthesis and downscaling of the available forecasts into farmer language through integration of the indigenous knowledge of the end users and the involvement of other non conventional partners.
c) Provision of other essential services like subsidized

farm inputs, access to credit, insurance, reliable and knowledgeable agricultural extension services and improved infrastructure.

d) Formation of farmer groups in the region as farmers working in isolation may not reap the full benefits that come with accurate and timely forecasts.

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