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Use and economic benefits of indigenous seasonal climate forecasts: evidence from Benin, West Africa

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ABSTRACT

Since immemorial times, farmers especially in Africa have built and transmitted orally from one generation to another a complex network of seasonal climate knowledge enabling them to lower climate variabilities and vagaries. Despite the prominent role of this knowledge system in smallholder farming, empirical studies relative to the production process, use and economic valuation of this knowledge to inform decision-making are scanty. Travel cost method, descriptive statistics and a two-step Heckman method are used to analyse the use and economic value of indigenous seasonal climate forecasts (ISCF) in Benin. ISCF were produced based on the observation of abiotic and biotic indicators in Kandi, Glazoué and Zè with the observations largely undertaken by local elders and professional traditional forecasters. Most farmers got ISCF either by travelling to visit a source of knowledge or by sacrificing their time. The use of ISCF increased a maize producer's net income by at least 3%, implying that ISCF are valuable goods. The main factors driving the use and value of ISCF were the use of fertilizer, large farm size, traditional African religions and access to market. Therefore, policy to promote the integration of indigenous forecasting knowledge with modern forecasting system should be taken.

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KEYWORDS

Indigenous seasonal climate forecasts; maize; total expenses approach; usefulness; valuation of forecasts; weak complementary assumption

1. Introduction

Many African farmers use indigenous knowledge (IK) to forecast climate patterns (Adanu et al., 2021; Nkuba et al., 2020; Orlove et al., 2010; Radeny et al., 2019; Roncoli et al., 2002; Tume et al., 2019). According to UNESCO (2017), IK refers to the understandings, skills and philosophies developed by societies with long histories of interaction with their natural surroundings. In a constrained environment characterized by rain-fed farming system, lack of financial resources and access to technologies, the success of an agricultural venture depends on the farmer managerial talent or ability to anticipate correctly future climate patterns and use it advantageously to reduce losses and achieve food security and target income (Adanu et al., 2021; Camacho-Villa et al., 2021). From times immemorial, farmers have learned to forecast the climate to gain information in order to improve their decision-making processes related to the production and marketing of agricultural goods. Farmers have used the appearance and/or the behavioural patterns of birds, insects, the movement and position of moon, sun, cloud, the direction and strength of the wind and plant phenology as data and signals that they process to obtain climate information for their livelihood activities (Adanu et al., 2021; Ingram et al., 2002; Nkuba et al., 2020; Orlove et al., 2010; Radeny et al., 2019; Rivero-Romero et al., 2016; Roncoli et al., 2002; Roudier et al., 2014; Speranza et al., 2010; Tume et al., 2019).

Farmers use indigenous seasonal/weather climate knowledge to plan for land to cultivate, the timing of land preparation, the purchase of seeds and fertilizer for planting, type

of crops to grow, type of agronomic practices to use and labour redistribution and allocation (Camacho-Villa et al., 2021; Radeny et al., 2019). However, the use of indigenous seasonal climate forecasts (ISCF) depends on factors such as sex, religion and education level (Ayal et al., 2015; Joshua et al., 2012). Roncoli et al. (2002) add that economic progresses coupled with societal transformation tend to erode customary systems and use of indigenous climate knowledge.

For rural and indigenous peoples, local knowledge informs decision-making about fundamental aspects of day-to-day life. Hiwasaki et al. (2014) and Ellen and Harris (1996) contended that IK is local, orally transmitted and is the consequence of practical engagement in everyday life, and is constantly reinforced by experience and trial and error. Two schools of thought are arguing on the benefits generated by the use of IK. The first school of thought postulates that IK is unscientific, backward and its use limits the adoption of technological innovations (Gilchrist et al., 2005; Gupta, 2007; Huntington, 2000). The second school of thought argues that IK is widely used by the population since several centuries and their survival through ages is a sign of their usefulness (Chang'a et al., 2010; Rivero-Romero et al., 2016). These controversies surrounding the IK have partly led to a lack of studies on the economic value of ISCF.

Improving our understanding on the accuracy, reliability and value of ISCF could increase awareness of their usefulness. Many investigations have previously explored indigenous seasonal climate knowledge (Adanu et al., 2021; Ayal et al., 2015; Camacho-Villa et al., 2021; Kalanda-Joshua et al., 2011; Nkuba

et al., 2020; Radeny et al., 2019; Rivero-Romero et al., 2016; Roncoli et al., 2002; Speranza et al., 2010). However, these studies emphasize mainly on the documentation, description and use of this IK by farmers. To the best of our knowledge, none of these studies tried to establish the net benefit (value) of ISCF.

Most developing countries are investing in the meteorological systems as a structural response to the emergency of climate change and variability and to increase food production. The significant and widespread use of the climate/weather information from the meteorological systems can justify the rational of these investments. The estimation of the net benefit of ISCF can also facilitate the dialogue between formal national meteorological system and local producers with the possibility of creation of participatory processes where climate services are coproduced and better disseminated between producers and end users. The estimation of the value of ISCF then can improve the use of enhanced or modern seasonal forecast. This estimation of the net benefit of ISCF can help to better preserve and document IK related to climate and this IK can be fundamental in the adaptation to climate change (Radeny et al., 2019; Tume et al., 2019). Moreover, Radeny et al. (2019) call for more studies on indigenous climate forecasting in order to better preserve this IK. The preservation and documentation of ISCF and the integration of ISCF in a national/local meteorological programme are costly and this study can allow cost-benefit analysis of climate services programmes or projects. In this study, we attempted to answer the following research questions: How is the ISCF produced and disseminated? How do farmers value the ISCF? What are the factors influencing the use of ISCF? The main objective

of this study is to analyse the use and economic value of ISCF used by maize producers in Benin.

2. Materials and methods

2.1. Conceptual framework

The success of small-scale agricultural venture depends on climate realisations and on the farmer managerial talent in general and on the farmer managerial talent to anticipate correctly future climate patterns in particular (Figure 1). The talent to forecast or get forecasts about future climate patterns helps farmers to improve decision-making, reduce losses and achieve food security and target income. Therefore, information about climate/weather is a fundamental factor in the success of small-scale farming. Climate/weather information can be obtained through two sources. Meteorologists can provide enhanced data and information on past, present and possible future states of the atmosphere (temperature, rainfall, wind, cloudiness and air quality) derived from direct observations using instruments and/or using the human senses. Using IK and without instruments, indigenous communities have mastered and performed a rich and complex system of forecasting based on the observation of appearance and movement of biotic and abiotic indicators.

The limited access to enhanced (scientific) information push farmers to rely on indigenous climate/weather forecasts. Having the information about the near and distant future (precipitations, wind speed and direction, cloudiness, relative humidity, minimum and maximum air and soil temperatures and pan evaporation), farmers can better

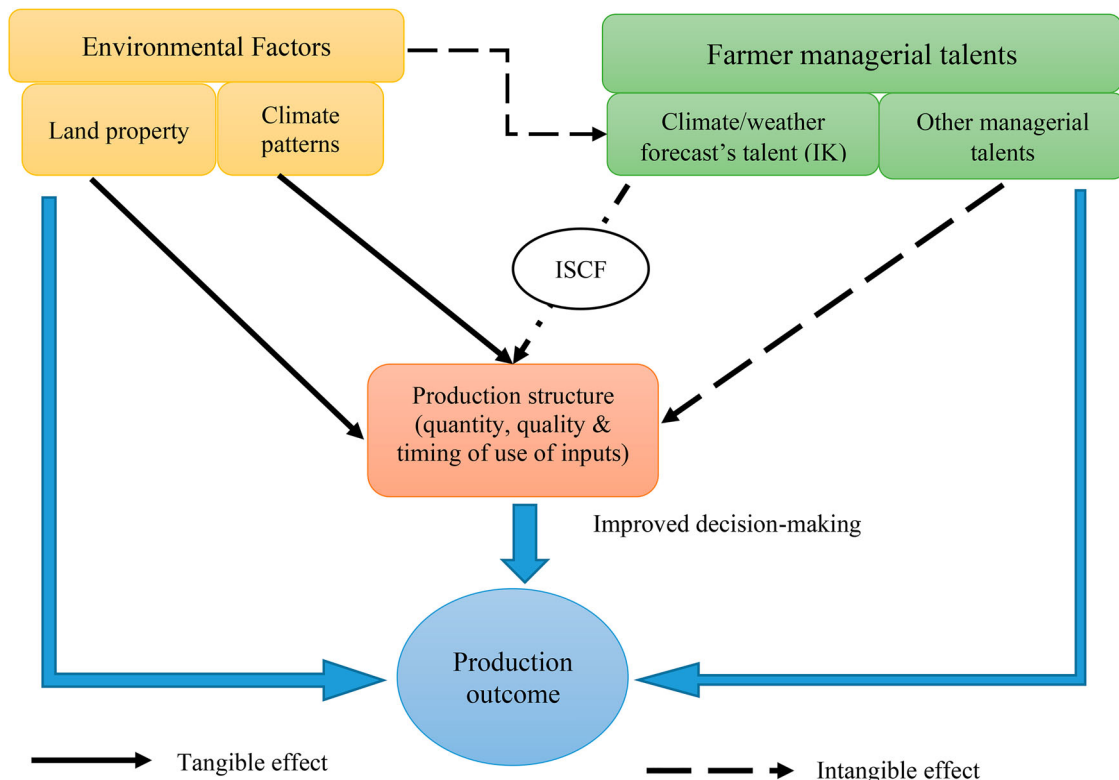


Figure 1. Conceptual framework.

choose which crop(s) to produce, manage efficiently inputs such as land, labour, fertilizer, financial assets devoted to each crop, adopt improved technologies and crops varieties, intensify production, invest more in production and storages facilities, adjust their daily decision (input timing and use, sowing period, marketing decisions), undertake activities that can minimize losses and risks due to adverse weather and so increase yield, quantity and quality of agricultural production and take advantage of favourable conditions (Hansen, 2002). By improving decision-making, ISCF contribute to the outcome of the agricultural venture and the difference between the outcome without ISCF and the one with ISCF is the net benefit of ISCF.

2.2. Theoretical framework

The true measure of the climate services benefits relates to improved decisions made by farmers. These benefits relate to the difference in net benefits or profits from using the selected forecast vis-à-vis other options. Net benefit is the difference between revenue and all costs of production including the cost to access forecasts. Two broad methods are used to value climate forecasts. Some studies conducted on assessment of the value of climate forecasts are based on ex-ante approaches (simulation models) whereas others are based on ex post approaches (observed, stated or revealed preference approaches) (Amegnaglo et al., 2017; Meza et al., 2008; Sultan et al., 2010). Revealed preference approach or surrogate market approach, which consists of inferring the value of non-market goods from the observed purchases of market goods necessary for the enjoyment of non-market goods by individuals, can also be used to value climate forecasts (World Meteorological Organization [WMO], 2015). To have ISCF, farmers generally either spend time observing the behaviour of different natural indicators like insects, birds, mammals, amphibians, trees and extra-terrestrials' objects or travel to consult professional traditional rainmakers, religious leaders, elders or friends. The time that farmers spend in observing different natural indicators can be used to determine the value of ISCF (WMO, 2015). The total expenses method can be used to estimate the benefits of ISCF for farmers who seek ISCF from external and internal sources.¹ The expenditures include travel fees towards the site where the forecast is received, the payments and/or donations made on the site in order to receive the ISCF.

The total expenses approach is often used in the context of the estimation of the cost of travel by an economic agent from a source to a site of interest as initially proposed by Hotelling (1947). The Hotelling approach, Travel Cost Method (TCM), can be envisioned as part of the general analytic group that can be called the total expenses approach (Douglas and Taylor, 1999). Total expenses approach allows for the use of this general method to value non-market goods beyond the traditional purview of recreational areas and environmental amenities and specifically allows for the valuation of non-market goods that can also be used as inputs to produce market goods (Douglas and Taylor, 1999).

Following Bockstael et al. (1987) and Bedate et al. (2004), an individual maximizes utility by choosing a flow

of informational services and a vector of other commodities, each of which may be produced by combining purchased inputs with time. Let $U(v, x)$ be the quasi-concave, twice-differentiable utility function of a representative consumer, where v is the number of visits to a source of information and x is a vector of all other goods consumed by the individual at a given price vector p . Each visit to the information site has a cost c .

$$\text{The consumer has an income: } Y = Y_0 + wt_w \quad (1)$$

where Y_0 is non-labour income, w is the wage rate per hour, t_w is the work hours,

The consumer has a certain amount of time: T_0

$$= t_w + vt_v \quad (2)$$

where t_v is the time spent on visit.

The user of the good must maximize its utility subject to time and income restrictions. The basic model implies that individuals are free to choose between work and recreation, in which case the opportunity cost of time is equal to the wage rate. In this manner, the utility function $U(v, x)$ is maximized subject to the following restrictions:

$$Y = cv + px \quad (4)$$

$$T_0 = t_w + vt_v \quad (5)$$

Bearing in mind the following relationships:

$$Y = cv + px = Y_0 + wt_w \quad (6)$$

$$Y_0 + w(T_0 - vt_v) = cv + px \quad (7)$$

$$Y_0 + wT_0 - v(wt_v + c) - px = 0 \quad (8)$$

The problem may be rewritten as:

$$\max_{v,x} \{U(v, x) + \lambda(Y_0 + wT_0 - v(wt_v + c) - px)\} \quad (9)$$

The first-order condition is:

$$\frac{dU}{dv} - \lambda(wt_v + c) = 0 \quad (10)$$

And making:

$$c^* = wt_v + c \text{ (total cost of visit)} \quad (11)$$

$$Y^* = Y_0 + wT_0 \text{ (maximum income)} \quad (12)$$

The demand function may be expressed as: v

$$= f(Y^*, p, c^*) \quad (13)$$

The demand for ISCF is function of the farmer's income, cost of visit to the information site and the price of other goods consumed. High income can allow individuals to devote a high share of their income to acquire ISCF. Also, the high cost of visits to information site reduces the profit of the farmer; therefore, there is little incentive for acquiring ISCF. High price of other goods consumed reduces farmer ability to spend more on the acquisition of ISCF.

2.3. Empirical model

A parametric approach was used to analyse factors that determine the benefits that farmers derived from the use of ISCF. The dependent variable is the logarithm of the expenditures incurred by farmers in order to enjoy the use of ISCF. The two-step Heckman selection model is based on the main hypothesis that the process that determines the producer decision to use or not ISCF is different from the process that determines the amount spent by the producer to get the ISCF (Heckman, 1979). This model also controls for the selection bias.

The model consists of two steps. Firstly, each farmer was asked whether they used ISCF or not. The respondent was expected to answer 'Yes' or 'No'. The probit model was estimated in order to obtain the Inverse Mill's Ratio (IMR). The probability that the farmer uses indigenous climate knowledge can be expressed as a function of independent variables in Equation (14) as:

$$P_i = A_0 + \sum_{j=1}^k A_j X_{ij} + U_i \quad (14)$$

where A_j is the coefficient of the j th socio-economic characteristic; X_{ij} is the j th socio-economic characteristic of the i th producer; U_i is the error term. The error term U_i is independently and identically distributed with a normal probability distribution function. The independent variables used are listed in Table 1.

If a given farmer uses ISCF, the second stage Ordinary Least Squares (OLSS) equation would then be as follows:

$$\ln TVE = \alpha + \beta' x_i + \gamma IMR + u_i \quad (15)$$

where $\ln TVE$ is the logarithm of the amount a farmer spends in order to have access to ISCF; β is a $k \times 1$ vector of unknown parameters; x_i is a $k \times 1$ vector of known constants and u_i are independently and normally $(0, \sigma^2)$. The independent variables used are presented in Table 1.

2.4. Data collection

2.4.1 Study area

A survey of maize producers was undertaken in Benin to obtain relevant data from individual maize producers to determine the aggregate benefits from the use of ISCF. The survey

elicited information from producers about the source and use and all the expenditures attributable solely to the use of the ISCF. Benin is characterized by three main climatic zones (Figure 2). Maize is produced in all of the three main climatic zones and is the major staple food in the country. Maize is also the most produced crop in the country. Each climatic zone has its own use of inputs such as water, fertilizer, herbicides for the production of maize.

2.4.2 Sampling techniques

A multi-stage cluster-based random sampling approach was used as the design to select the respondents of the study (Table 2). The first stage of the design consisted of the random selection of one municipality per climatic zone. The second stage of the selection process consisted of the random selection of three districts per selected municipality. The third stage of the selection process consisted of the selection of two villages in each district. The fourth and final stage was the selection of farmers to be interviewed with a structured questionnaire in the randomly selected villages. The optimal sample size for the number of farmers selected for the whole study was 323.² Oversampling was used and hence 396 farmers were chosen for the study indicating an oversampling of about 22.6%. This oversampling was done due to the possibility of some farmers refusing to participate in the study. In total, 396 farmers were interviewed, but data on 354 farmers were used for the analysis due to some missing data for 43 farmers.

2.4.3. Estimation of the economic value of ISCF

Farmers spend time in observing behaviour and phenology of natural indicators and the sacrifice of time made by farmers in order to produce ISCF is valued by multiplying the time used by the average wage rate per hour in Benin as presented in Equation (16). For this study, the median wage per hour in the agricultural sector estimated by Besamusca et al. (2013) is used to value the time farmers sacrificed to generate their own forecasts. Besamusca et al. (2013) estimated that the median wage per hour in agricultural sector in Benin was USD 0.524 in 2012 based on a sample of 2002 individuals.

$$TEV_1 = \text{Time spent} \times \text{Median wage per hour rate} \quad (16)$$

where TEV_1 is the total economic value of ISCF based on own production.

Table 1. Variable description for the two-step Heckman models.

Variables	Description	Measurement	Expected signs
SEX	Sex	Dummy (male = 1, female = 0)	+
LAND	Current Farm Size	Hectares	+
EXPERIENCE	Maize Farming Experience	Years	+
EDUCATION	Education	Dummy (1 = post-primary and 0 otherwise)	-
OFFFARM	Off-Farm Participation	Dummy (Yes = 1, No = 0)	-
RELIGION	Traditional Religion Adherents	Dummy (Yes = 1, No = 0)	+
MARKET	Access to Market	Dummy (Yes = 1, No = 0)	-
EXTENSION	Access to Extension Services	Dummy (Yes = 1, No = 0)	-
CREDIT	Access to Credit	Dummy (Yes = 1, No = 0)	-
FBO	FBO Membership	Dummy (Yes = 1, No = 0)	-
FERTILIZER	Quantity of Fertilizer Used	Kilogram	+
REGION1	Kandi	Dummy (Kandi = 1, Zè and Glazoué = 0)	
REGION2	Glazoué	Dummy (Glazoué = 1, Zè and Kandi = 0)	

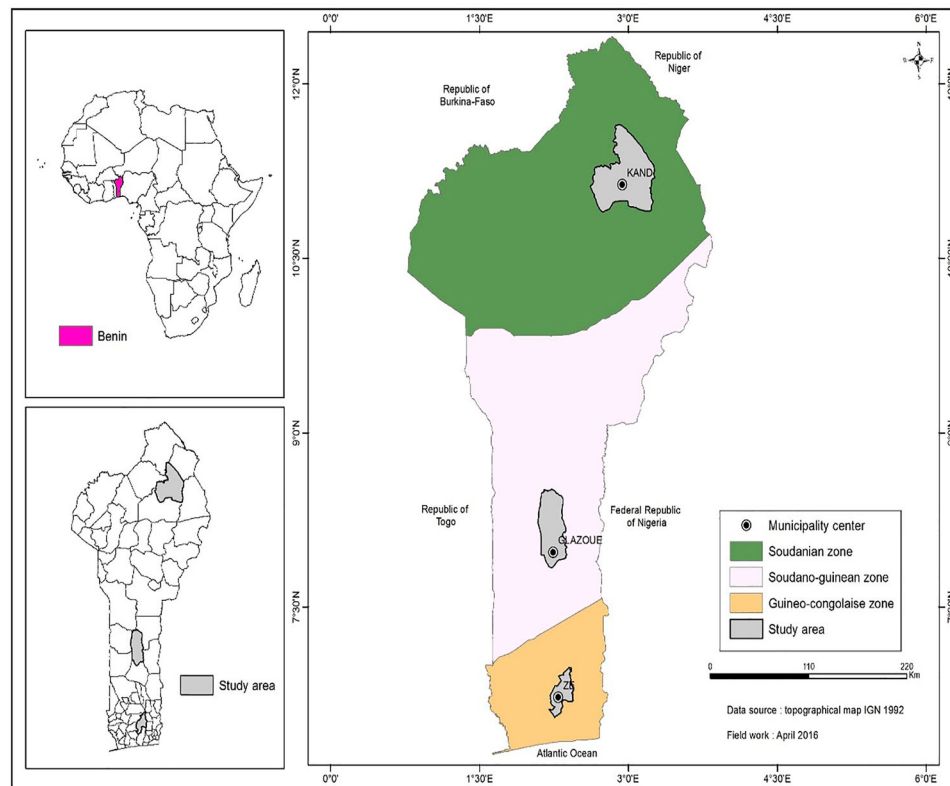


Figure 2. Location of the study areas and climatic zones in Benin.

Table 2. Summary of sampling procedure.

Sampling steps	Population	Techniques	Results
First	Communes: Selection of 03 communes out of 77	Purposive sampling: Identification of commune per climatic zone; Random sampling: Names of the communes are written on pieces of paper and three districts are randomly picked per municipality;	Kandi from the 14 communes in the Soudanian climate zone, Glazoué from the 15 communes in the Sudan-Guinean climate zone, Zè from the 34 communes in the Sub-humid Guinean Climate zone.
Second	Districts: Selection of 03 districts per selected communes	Random selection: Names of the districts are written on pieces of paper and three districts are randomly picked per commune selected;	Sonsoro, Kassakou and Donwari from the 10 districts of Kandi; Aklampa, Asanté and Zaffé from the 10 districts of Glazoué; Tangbo-Djevie, Sedje-Denou and Djigbé from the 11 districts of Zè.
Third	Villages: Selection of two villages per districts	Random selection: Names of the villages are written on pieces of paper and two villages are randomly picked per districts selected	Two villages are randomly selected from each district making up 18 villages for the nine districts and the three municipalities.
Fourth	Farmers: Selection of farmers per village	Random selection: Random selection of farmers based on the list based on the availability	Twenty-two (22) farmers are randomly selected from each village based on identifiable clusters of houses and huts in the different geographical areas of the village. A consultation of the Chief of the Villages selected helps to get an approximate number of farmers known to be available in the village at the time of the study.

Farmers also get ISCF from external sources and TEV_2 is the total economic value of ISCF from these sources. Farmers generally get the ISCF from external sources by using two different strategies. Farmers get the forecasts individually or by using community-based mechanisms. In some villages, farmers contribute to organize public consultation days before the starting of the rainy season. Other farmers seek the forecasts privately and have to travel to the source of ISCF and he has to pay for the service. The payment can be in cash or in-kind. All the in-kind payments were valued at market prices. In this part, travelling time and time spent on the forecasts site were not valued because most farmers do not spend

significant time and they travel to the forecast sites during their leisure (free) time.

The total economic value of ISCF from external sources (TEV_2) can be aggregated as follows:

$$TEV_2 = \text{cost of getting ISCF through group mechanisms} + \text{cost of getting ISCF individually} \quad (17)$$

The cost of getting ISCF individually is the number of visits times the sum of travel cost and on-site payment for the forecasts. Since these travels to gather seasonal information are

part of habitual traditional (and religious and/or festive) social activities; in that case, the trip has more purposes and only a part (50%) of the cost should be used as the indicative value of the expected benefits of using the seasonal information. The on-site payment can be in cash or in-kind. The in-kind payments were valued at market prices. Therefore, the total economic value of ISCF from external sources (TEV_2) can be rewritten as follows:

$$\begin{aligned} TEV_2 = & \text{cost of getting ISCF through group mechanisms} \\ & + (0.5 * \text{Travel cost to site} + \text{On site payments by farmers}) \\ & * \text{number of visits} \end{aligned} \quad (18)$$

The total economic value (TEV) of ISCF is the sum of the value of the time used by farmers to produce their own ISCF (TEV_1) and the cost that farmers incur to obtain ISCF from external sources involving the costs of getting forecasts using group mechanisms, the travel cost of an individual to a particular site to obtain forecasts and on-site payments to access the forecasts once the farmer has reached the site (TEV_2).

$$TEV = TEV_1 + TEV_2 \quad (19)$$

Once the individual economic value of ISCF has been estimated, it was multiplied by the number of maize farmers in Benin in order to estimate the total economic value of ISCF at the national level.

Descriptive statistics including frequencies and means were used to analyse the different sources of production of ISCF, proportion of farmers acting on ISCF and dissemination channels of these forecasts. Descriptive statistics (frequencies and percentages analysis) were also used to determine the type of information provided by indigenous meteorological schemes and the production step at which each type of information produced is used. A proportion test was performed to analyse the regional differences across responses.

3. Results and discussion

3.1. Socio-economic characteristics of survey respondents

About 38% of farmers interviewed came from Kandi Municipality, 32% from Zè and 30% from Glazoué (Table 3). Almost half of the respondents were Christians, one-third was adherents of the traditional African religions and the rest (about 20%) were Muslims. About 73% of the respondents were male and one-third of the farmers were young (18–35 years). The mean age of sampled farmers was about 42 years and users of ISCF were slightly older than non-users. Respondents with no schooling (formal education) constituted the largest group (61.6%), while primary school leavers were the second most prominent class of respondents (28.5%). The average farm size for the whole group was about 3.9 hectares and users of ISCF had slightly over three times the farmland of non-users. The mean farming experience on maize production is 22 years. Users of ISCF are more experienced (about 7 years) than non-users and this is not surprising knowing the role of age in the production process of ISCF. For the majority of farmers (73%), maize was their main crop and the majority

of the farmers (57.3%) declared agriculture as their sole source of income.

Only one-third of farmers interviewed interacted with extension services during the last three farming seasons (2012–2014), with a higher proportion of interaction in the north (66%) due to the production of cotton in the municipality of Kandi (Table 3). About 57% of farmers applied fertilizer during the last cropping season.

3.2. Use of indigenous seasonal climate knowledge by farmers

Farmers based some of their farming decisions on ISCF. A large majority (83%) of farmers declared that they used indigenous seasonal climate knowledge to plan ahead their farming operations during the 2014 major cropping seasons. Similar results were obtained by Chang'a et al. (2010) and Elia et al. (2014) in Tanzania, Roncoli et al. (2002) in Burkina Faso, Speranza et al. (2010) in Kenya, Kalanda-Joshua et al. (2011) in Malawi, Nkuba et al. (2020) in Uganda, Tume et al. (2019) in Cameroun, Radeny et al. (2019) in Ethiopia, Tanzania and Uganda. The proportion of farmers acting on ISCF decreased as one comes closer to the coastal regions. Indeed, during the 2014 farming season, 96.3, 88.7 and 61.9% of farmers in Kandi, Glazoué and Zè used ISCF to guide their decision-making, respectively (Table 4). A regional analysis was performed because the three municipalities are significantly different in terms of religious and cultural practices, climatic and economic conditions and agricultural production system (Amegnaglo et al., 2017; INSAE, 2015).

Few farmers (7.4%) produced their own ISCF, 33.8% of farmers got their forecasts from other members of their community and 58.8% of farmers used both sources (Table 4). Farmers who did not have indigenous seasonal climate knowledge allowing them to forecast climate by themselves consulted various sources of information such as local elders, professional traditional forecasters, religious leaders and friends in decreasing order of importance, respectively (Table 4). Most of the farmers who got forecasts from external sources consulted more than one source and the consultation of multiple external sources explained the fact that the sum of the proportion of use of the various sources exceeded 100%. The difference in external sources used across regions was certainly due to religious differences across the three regions as suggested by Roncoli et al. (2002) and Ingram et al. (2002).

3.3. Indigenous indicators used by farmers in seasonal climate forecasting

Two-thirds of maize farmers who used seasonal climate forecasts in Benin were aware of the indicators or elements used to generate indigenous meteorological knowledge. This proportion ranged from 58.6% in the southern zone (Zè) to 73.8% in the northern zone (Kandi). They indicated different indigenous indicators of seasonal climate forecasting. The most used elements to forecast climate were trees (72.7%), birds (72.2%), extra-terrestrial objects (61.1%), winds (58.9%), insects (44.9%) and sky (41.9%) (Table 5). The vast majority of farmers (91%) who based their climate forecasts

Table 3. Summary of socio-economic characteristics of survey respondents per municipality based on averages and frequencies.

Items	All farmers (n = 354)		Users (n = 299)		Non-Users (n = 60)		ttest/P-Value
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	
Sex (percentage male)	73.1	44.4	78.9	40.9	45.0	50.2	.0000***
Mean Age (Years)	41.7	12.6	43.3	12.8	33.9	8.2	.0000***
No education at all	61.6	48.7	61.9	48.6	60.0	49.4	.7830
Primary School	28.5	45.2	28.9	45.4	26.7	44.6	.7265
Post Primary School	9.9	29.9	9.2	28.9	13.3	34.3	.3278
Mean number of years of schooling	2.4	3.8	2.4	3.8	2.7	3.9	.6188
Christian	48.0	50.0	40.8	49.2	83.3	37.6	.0000***
Muslim	21.2	40.9	24.1	42.9	6.7	25.1	.0025***
Traditional African Religions	30.8	46.2	35.0	47.8	10.0	30.2	.0001***
Mean Farm size (ha)	3.9	4.4	4.4	4.6	1.5	1.5	.0000***
Use of fertilizer (%)	56.8	49.6	65.0	47.8	16.7	37.6	.0000***
Quantity of fertilizer used (Kg/Ha)	94.7	104.5	109.2	105.9	23.6	58.8	.0000***
Off-farm activity' Participation (%)	42.7	49.5	36.1	48.1	75.0	43.7	.0000***
Maize farming Experience (years)	22.2	11.7	23.3	11.9	16.4	8.4	.0000***
Access to extension services (%)	33.9	47.4	37.4	48.5	16.7	37.6	.0019***
Access to credit (%)	52.2	50.0	52.4	50.0	51.7	50.4	.9199
Access to market (%)	89.8	25.2	93.2	25.2	73.3	57.6	.0000***
FBO's membership (%)	12.7	33.3	13.6	34.4	8.2	27.6	.2458

* denotes statistical significance at the 10% level; ** denotes statistical significance at the 5% level; *** denotes statistical significance at the 1% level.

on their own knowledge used more than one element. Sometimes when the indigenous indicators used to provide forecasts are contradictory, religious rituals are performed by professional traditional forecasters to get a clearer picture of the situation (Ingram et al., 2002).

3.4. Farmers' response strategies to ISCF

Based on ISCF, farmers generally used non-intensified options such as change of sowing date, change of area devoted to crops, the substitution of crops, change of crop density and change of crop variety in their production decision. These results are similar to those found by Camacho-Villa et al. (2021) in Mexico and Radeny et al. (2019) in Ethiopia, Tanzania and Uganda. Intensified options (*i.e.* use and increase of organic and inorganic fertilizer) were also used. Farmers also mixed the intensified and non-intensified strategies with the aim to decrease production risks. Table 6 presents responses (strategies) used by maize farmers in Benin. The majority of the farmers used more than two strategies (intensified and non-intensified). In all cases, farmers responded by either adopting non-intensified strategies or by mixing intensified and non-intensified strategies. The most commonly used non-intensified strategies were the change of planting date (76.3%), change of crop variety/type (62.8%) and change of area planted by crop (49.2%) (Table 6). When farmers have access to ISCF, they choose the cultivar that can maximize their return. In the present study,

about 62.8% of farmers interviewed responded to ISCF obtained by changing crop variety. The change of crop variety was higher (Table 6) in Kandi and Glazoué, where farmers were better off than in Zè. The change of crop acreage was the third most employed response strategy by farmers in Benin (Table 6). Almost all the farmers interviewed grew at least two crops and each year they have to decide the quantity of inputs that must be devoted to each crop. Farmers can reduce the quantity of land devoted or allocate zero lands to some crops with the aim to increase the quantity for other crops more suited for the coming season based on the climate predictions.

About 41% of farmers intensified their production after getting ISCF (Table 6). This option was mostly used in areas (Kandi and Glazoué) where farmers had better access to agro fertilizer (NPK + Urea). The low use of this option in Zè was certainly due to the low use of agro fertilizer in this area and a policy should be undertaken to increase the use of fertilizer (organic and chemical) in this area. Farmers who were previously using fertilizer with the access to meteorological information would maintain the current quantity of fertilizer used or increase it (Table 6).

Table 5. Indigenous indicators of climate forecasting employed by maize farmers expressed in percentage.

Indigenous Indicators	All farmers	Kandi	Glazoué	Zè
Behaviour of Birds	72.2	76.0 ^A _B	55.7 ^C	87.8
Behaviour of Insects	44.9	45.8	42.6	46.3
Behaviour of Mammals	14.6	18.8 ^A	6.6 ^C	17.1
Behaviour of Amphibians	21.7	37.5 ^A _B	3.3 ^C	12.2
Phenology of Trees	72.7	84.4 ^A _B	55.7 ^C	70.7
Behaviour of Extra-terrestrial Objects (Moon, Sun & stars)	61.1	65.6 ^B	63.9 ^C	46.3
Behaviour of Sky	41.9	62.5 ^A _B	29.5 ^C	12.2
Behaviour of Wind	58.9	63.5 ^B	63.9 ^C	39.0

A, B and C denote statistical significance at 5% % based on proportion test between Kandi and Glazoué, Kandi and Zè and Glazoué and Zè, respectively.

Table 4. Sources of ISCF in Benin Expressed in percentage.

	All farmers	Kandi	Glazoué	Zè
Proportion of farmers using ISCF	83.0	96.3 ^{A, B}	88.7 ^C	61.9
Sources of ISCF				
Own Production	7.4	6.9 ^B	3.2 ^C	13.5
External Production	33.8	26.2 ^B	35.8	44.6
Both	58.8	66.9 ^B	61.7 ^C	41.9
External sources of ISCF				
Local Elders	86.2	94.2 ^B	90.9 ^C	62.7
Religious leaders or priests	48.5	19.0 ^{A, B}	65.9 ^C	83.0
Friends	7.3	8.2	5.6	7.8

A, B and C denote statistical significance at 5% based on proportion test between Kandi and Glazoué, Kandi and Zè and Glazoué and Zè, respectively.

Table 6. Response strategies used by maize farmers when planning for maize production after receiving ISCF in Benin expressed in percentage.

Preparedness Techniques	All farmers	Kandi	Glazoué	Zè
Non Intensified Strategies				
Change of planting dates	76.3	86.2 ^{A, B}	67.0	71.6
Change of crop varieties	62.8	73.1 ^{A, B}	83.5 ^C	17.6
Change crop acreage	49.2	39.2 ^A	71.1 ^C	37.8
Change of crop types	30.9	52.3 ^{A, B}	14.4	14.9
Change of land preparation	25.6	20.0 ^B	15.5 ^C	48.6
Change of crop spacing	24.9	40.8 ^{A, B}	9.9	17.6
Change of fields to plant maize	10.6	17.7 ^A	0.0 ^C	12.2
Change of fertilizer application date	14.3	26.9 ^{A, B}	8.2 ^C	0.0
Change of chemicals application date	7.0	11.5 ^B	6.2 ^C	0.0
Intensified Strategies				
Increase the use of fertilizer	41.2	63.1 ^{A, B}	41.2 ^C	2.7
Increase of the quantity of chemicals	10.3	15.4 ^B	9.3 ^C	2.7

A, B and C denote statistical significance at 5% % based on proportion test between Kandi and Glazoué, Kandi and Zè and Glazoué and Zè, respectively.

3.5. Cost of using indigenous seasonal climate forecasts (ISCF)

3.5.1. Value of time used to produce ISCF by farmers

About 56% of the 198 farmers interviewed spent some time observing behaviour and phenology of natural indicators as a means of generating their own seasonal climate forecasts, suggesting that approximately two-thirds of farmers used ISCF. On average, a farmer spent 4 h and 20 minutes per season (Table 7) in observing behaviour and phenology of natural indicators such as birds, insects, plants, amphibians, extra-terrestrial objects. The computation of the total economic value of ISCF based on own forecasts (TEV_1) gives an average benefit of 451.2 USD for the 198 farmers producing their own forecasts. The benefit per farmer is around 2.28 USD for the 2014 major cropping season.

3.5.2. Value of ISCF acquired by farmers through external sources

About three-quarters of farmers interviewed got their ISCF through community-based mechanisms (Table 8). This strategy certainly allowed farmers to discuss forecasts among themselves and share knowledge and experience. On average, a farmer paid 12 USD as a contribution for the organization of the public consultation days. The total amount of money spent for the whole sample to get ISCF through community-based mechanisms was about 2853.5 USD. One-third of farmers who got seasonal climate forecasts from external sources sought the forecasts privately. Farmers (89 farmers) who sought ISCF privately consult professional traditional

Table 8. Average cost incurred in getting ISCF through community-based mechanisms.

Type	All farmers	Kandi	Glazoué	Zè
Individual mechanism	12.9	19.0	6.6	10.0
Community-based mechanism	67.6	55.4	92.3	55.0
Both	19.5	25.6	1.1	35.0
Individual share in USD in community-based mechanisms	12.04 (14.56)	17.97 (18.66)	5.97 (7.38)	10.83 (9.72)

*The figures in brackets are the standard deviations of the means.

forecasters (72.5%), religious leaders (16.5%) and local elders (11%).

On average, a farmer travelled about 4 km to reach the information site and spent 2.605 USD in terms of actual transportation costs (Table 8). In this paper, travelling time and time spent on the information site were not valued because most farmers did not spend significant time on the site. Moreover, they travelled to the site during their leisure time. Majority (94.5%) of farmers paid consultation fees (cash or in-kind) before getting the ISCF. The most common payment form used to enjoy ISCF from external sources was cash payment. About two-thirds of farmers interviewed used cash payment only, while the other one-third of farmers used a mix of cash and in-kind payments. On average, a farmer spent 16 (± 17.46) USD. Farmers in Glazoué and Zè spent a higher amount in consultation fee (cash or in-kind) compared to farmers in Kandi. This was due to the difference in development between the three municipalities. Kandi was better off in terms of wealth than Glazoué and Zè (INSAE, 2015). Poor farmers spent more because they had low adaptive capacity to production risks due to lack of resources and absence of other climate change coping strategies (Roncoli et al., 2009; Vogel, 2000; Ziervogel and Calder, 2003).

The cost of getting ISCF individually was around 3706.05 USD for the whole community (Table 9). On average, a farmer who sought ISCF individually spent about 41.64 USD. This amount covered transportation costs, consultation fees and other stationary fees. This amount was much greater than the average cost of getting indigenous forecasts through community-based mechanism because community-based mechanism helped to avoid transportation fees to the source of forecasts and also reduced significantly payment on the site of forecasts. The computation of the total economic value of

Table 7. Distribution of time spent in observation of natural indicators.

	All farmers	Kandi	Glazoué	Zè
Number of farmers spending some time to get forecasts	198	96	61	41
Less than one hour	32.8%	32.3%	32.8%	36.6%
[1–2] hours	13.6%	9.4%	18.0%	17.1%
[2–3] hours	14.7%	11.4%	18.0%	17.1%
[3–4] hours	10.1%	7.3%	13.1%	12.2%
[4–5] hours	9.6%	12.5%	1.6%	14.6%
[5–10] hours	10.1%	15.6%	6.6%	2.4%
More than 10 hours	9.1%	12.5%	9.8%	0%
Average time spent	4.35 (5.00)	5.26 ^A (5.85)	4.07 ^C (4.77)	2.63 (1.70)
Opportunity cost of time spent (USD)	2.28 (2.62)	2.76 ^A (3.06)	2.13 ^C (2.50)	1.38 (0.89)

* A, B and C denote statistical significance at 5% based on proportion test between Kandi and Glazoué, Kandi and Zè and Glazoué and Zè, respectively and 1 US dollar = 500 FCFA. The figures in brackets are the standard deviations of the means.

Table 9. Costs incurred to seek ISCF individually.

Source	All farmers	Kandi	Glazoué	Zè
Traditional forecaster	34.82 (53.49)	31.29 (52.63)	20.00 (20.89)	45.35(59.96)
Elders	1.79 (7.80)	0.80 (3.17)	10.48 (20.39)	1.52 (8.03)
Religion leaders	5.02 (22.30)	8.28 (28.25)	n.a.	n.a.
All sources	41.64 (54.35)	40.37 (55.13)	30.48 (19.05)	46.87 (59.30)

ISCF from external sources (TEV_2) amounted to a total of 559.55 USD and to an average of 24.84 USD per farmer as a cost of getting ISCF from external sources.

3.5.3. Total economic value of ISCF

The total economic value of ISCF for the entire group of 354 farmers interviewed over the 2014 maize cropping season was 7010.75 USD and this amount represented the minimum gain derived from the use of ISCF. This translated to 23.84 USD per farmer for only farmers who used ISCF. The use of ISCF increased a maize producer's net income by at least 3%. These results suggest that, given the revealed preference approach based on expenditures actually incurred to consume a good, ISCF are valuable goods.

3.5.4. Factors affecting the economic value of ISCF

A two-step Heckman econometric analysis indicated that the coefficient of the inverse Mill's ratio (IMR) was not statistically significant (Table 10). This means that there was no selection bias resulting from the use of non-zero amount values. Therefore, the second stage OLS is useful in determining the mean expenditure.

The results of the probit regression showed that at the 10% level of statistical significance, all the variables were significant. Men male farmers were more likely to use ISCF than their female counterparts. Ayal et al. (2015) suggested that the ISCF were the prerogative of men even though women were not excluded from getting and using the forecasts based on this knowledge. As expected, adherents of traditional African

Table 10. Results of the Heckman two-step selection regression analysis of the determinants of benefits of ISCF in Benin.

Variable	Probit			OLS		
	Coeff.	t-value	P-values	Coeff.	t-value	P-values
SEX	0.6721	2.73	.006***	0.0738	0.41	.682
EXPERIENCE	0.0273	2.119	.035**	-0.0008	-0.11	.914
EDUCATION	-0.8589	-2.52	.012**	0.0093	0.04	.971
LOG (LAND)	0.5520	3.00	.003***	0.4088	3.50	.000***
LOG (FERTILIZER)				0.1053	2.55	.011**
MARKET	0.5080	1.45	.148	0.5037	1.79	.073*
EXTENSION				-0.1829	-1.01	.313
CREDIT	-0.0737	-0.30	.761	-0.3621	-2.26	.024**
FBO	0.5307	1.16	.106	0.1953	0.87	.382
OFFFARM	-0.6782	-2.75	.006***	-0.3314	-2.02	.043**
RELIGION	0.9729	3.26	.001***	0.5354	2.36	.018**
REGION1	1.5814	4.35	.000***	0.1642	0.45	.652
REGION2	0.9047	2.89	.004***	-0.9169	-3.84	.000***
CONSTANT	-1.3432	-2.72	.006***	1.3937	2.41	.016**
Lambda				0.3191	0.58	.561
Number of obs. = 354; Censored obs. = 60; Wald chi2 = 88.77; Prob > chi2 = 0.0000;						

* denotes statistical significance at the 10% level; ** denotes statistical significance at the 5% level; *** denotes statistical significance at the 1% level.

religions were more likely to use ISCF than non-adherents. Similarly, Joshua et al. (2012) found that Christianity reduces the farmers' willingness to use ISCF forecasts in Zimbabwe. Similarly, farmers with post-primary school educational qualifications were less likely to use ISCF given their lower attachment to the indigenous cultural values as they would have been less separated from their cultural background due to less Western educational influences (Ayal et al., 2015).

Participation in off-farm work reduced the probability of using ISCF. Experience in maize farming increases the likelihood of use of ISCF suggesting that farmers with increased levels of experience searched for various forms of information to reduce the risk of farm operations. Further, the experience would allow a farmer to have more insight into the use of ISCF and might have recognized/realized usefulness of these forecasts compared to less experienced farmers.

Farm size is positively and significantly related to the likelihood of the use of ISCF. ISCF reduced losses due to the risks induced by large farm size. Considering the geographical location, the results indicated that farmers living in Kandi were more likely to use ISCF than farmers living in Zè. Similarly, farmers living in Glazoué were more likely to use ISCF than farmers living in Zè. The base municipality, Zè, is an area that is much closer to the economic capital city of Benin, Cotonou. Hence farmers in Zè were less likely to have access to these forecasts because Roncoli et al. (2002) postulate that economic progresses coupled with societal transformation tend to erode customary systems and use of IK such as indigenous seasonal climate knowledge.

The results of the OLS regression showed that adherents of traditional African religions valued more ISCF than non-adherents. Also, access to market increased the benefits that farmers derived from ISCF and therefore policymakers should facilitate access to market by reducing transportation costs and ensuring market availability in order to improve farmers' livelihoods. Farm size and intensity of use of fertilizer positively and significantly affected the benefits farmers derived from the use of ISCF. Use of ISCF reduced losses due to the production risks related to the use of fertilizer and large farm size.

Access to credit significantly reduced benefits from ISCF. The negative relationship between access to credit and adoption of improved technologies can either be due to the inadequate access to credit (Diagne and Zeller, 2001) or the allocation of credit obtained for production to smooth the consumption (Feder et al., 1990). Considering the geographical location, the results indicated that farmers in Glazoué derived less benefits from the use of ISCF compared to farmers living in Kandi and Zè. This may be due to the high climate instability experienced in Glazoué, this area is located in the transitional zone.

4. Conclusions and policy recommendations

This paper analyses the economic value of indigenous seasonal climate forecasts (ISCF) based on travel cost method, descriptive statistics and a two-step Heckman method and a random survey of 354 maize farmers. Most farmers act on seasonal climate forecasts in Benin and receive their forecasts from traditional schemes. The indigenous seasonal climate

knowledge is based on behaviour and phenology of trees, birds, extra-terrestrial objects, winds, insects and sky. The most non-intensified strategies use are, in descending order, change of planting date, change of crop variety, change of area planted by crop, change of crops planted, change of land preparation, change of crop spacing and change of crop fields. Farmers generally get the indigenous forecasts either by producing their own forecasts based on observation of natural elements or by travelling to consult a source of information. The valuation of the time spent and of the cost of overcoming the distance between a farmer's house and information site gives a minimum benefit of 7010.75 USD for the whole sample of farmers interviewed. These results suggest that indigenous seasonal climate knowledge in Benin is of substantial economic importance, especially in a context of smallholder farming system and of climate change/variability. The indigenous seasonal climate knowledge may be the starting point of an ex-ante adoption of climate technologies.

The main factors driving the use and value of ISCF are the use of fertilizer, large farm size, traditional African religions and access to market. Regular interactions with formal institutions (formal education system and extension and credit services) tend to reduce the use and value of ISCF. The results of the regressions hold potential policy interventions. Policy-makers should find ways of integrating formal institutions in the design of climate services programmes and these programmes should particularly target smallholders and women. Investing in fertilizer development programme and improving access to markets in Benin may increase the use and value of ISCF.

The results of this work show the societal, economic and cultural importance of indigenous seasonal climate knowledge for farmers. Therefore, the resource should be committed to studying and preserving indigenous knowledge in general and indigenous seasonal climate forecasts especially. Policy-makers should also integrate these indigenous forecasts in national meteorological and agricultural development strategies. This work also demonstrated the farmers' need for seasonal climate information and so resources can be committed to studying and producing high-quality modern seasonal climate forecasts for farmers. Also, policies that can improve farmers' access to inputs and resources must be adopted by policymakers.

The valuation of ISCF in Benin focuses only on one crop (maize); however, a large majority of farmers in Benin produce at least two crops. The exclusion of other crops in the analysis may reduce the confidence that can be attached to the general conclusions derived from this analysis. Further in-depth analysis is needed in order to understand and refine the role and value of ISCF in multi-cropping system. Furthermore, the travel cost method used for the valuation of ISCF does not capture non-use value of these forecasts and may lead to an under-estimation of the value of these forecasts. Direct elicitation methods or impact evaluation methods can be used on repeated data in order to reduce bias. Finally, the use of Heckman's approach employed in this study does not capture the average treatment effect (ATE) of the use of indigenous climate knowledge on farmers' expenditures, future studies could explore that possibility.

Notes

1. In this study, external sources mean forecasts that are not produced by the end-users of the forecasts. External sources include local elders, professional traditional forecasters, religious leaders and friends.
2. The optimal sample size for the number of farmers selected for the whole study was 323. The determination of the optimal sample size is based on works of Babbie (2016) dealing with the sampling from very large population sizes.

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References

- Adanu, S.K., Abole, T., & Gbedemah, S.F. (2021). Use of indigenous knowledge to predict rainfall in the Yendi Municipality, Ghana. *GeoJournal*, 8. <https://doi.org/10.1007/s10708-021-10403-8>
- Amegnaglo, C.J., Anaman, K.A., Mensah-Bonsu, A., Onumah, E.E., & Amoussouga Gero, F. (2017). Contingent valuation study of the benefits of seasonal climate forecasts for maize farmers in the Republic of Benin, West Africa. *Climate Services*, 6, 1–11. <https://doi.org/10.1016/j.cliser.2017.06.007>
- Ayal, D.Y., Desta, S., Gebru, G., Kinyangi, J., Recha, J., & Radeny, M. (2015). Opportunities and challenges of indigenous biotic weather forecasting among the Borena herders of Southern Ethiopia. *SpringerPlus*, 4(617), 1–11. <https://doi.org/10.1186/s40064-015-1416-6>
- Bedate, A., César, L., & Ángel, J. (2004). Economic valuation of the cultural heritage: Application to four case studies in Spain. *Journal of Cultural Heritage*, 5(1), 101–111. <https://doi.org/10.1016/j.culher.2003.04.002>
- Besamusca, J., Tijdens, K., Tingum, E.N., & Alinsato, S.A. (2013). *Salaires au Bénin. Rapport d'enquête WageIndicator 2012*. Amsterdam.
- Bockstael, N.E., Strand, I.E., & Hanemann, W.M. (1987). Time and the recreational demand model. *American Journal of Agricultural Economics*, 69(2), 293. <https://doi.org/10.2307/1242279>
- Camacho-Villa, T.C., Martínez-Cruz, T.E., Ramírez-López, A., Hoil-Tzuc, M., & Terán-Contreras, S. (2021). Mayan traditional knowledge on weather forecasting: Who contributes to whom in coping With climate change? *Frontiers in Sustainable Food Systems*, 5. <https://doi.org/10.3389/fsufs.2021.618453>
- Chang'a, L.B., Yanda, P.Z., & Ngana, J. (2010). Indigenous knowledge in seasonal rainfall prediction in Tanzania: A case of the South-western Highland of Tanzania. *Journal of Geography and Regional Planning*, 3, 66–72. <https://doi.org/10.7553/80-1-1395>
- Diagne, A., & Zeller, M. (2001). Access to Credit and Its Impact on Welfare in Malawi. International Food Policy Research Institute Report 116, Washington, D.C.
- Douglas, A.J., & Taylor, J.G. (1999). A New model for the travel cost method: The total expenses approach. *Environmental Modelling & Software*, 14(1), 81–92. [https://doi.org/10.1016/S1364-8152\(98\)00060-7](https://doi.org/10.1016/S1364-8152(98)00060-7)
- Elia, E.F., Mutula, S., & Stilwell, C. (2014). Indigenous knowledge use in seasonal weather forecasting in Tanzania: The case of semi-arid central Tanzania. *South African Journal of Libraries and Information Science*, 80(1), 18–27. <https://doi.org/10.7553/80-1-180>
- Ellen, R., & Harris, H. (1996). Concepts of Indigenous Environmental Knowledge in Scientific and Development Studies Literature – A Critical Assessment. Draft Paper Presented at East-West Environmental Linkages Network workshop 3, Canterbury.
- Feder, G., Lau, L.J., Lin, J.Y., & Luo, X. (1990). The relationship between credit and productivity in Chinese agriculture: A microeconomic model of disequilibrium. *American Journal of Agricultural Economics*, 72(5), 1151–1157. <https://doi.org/10.2307/1242524>
- Gilchrist, G., Mallory, M., & Merkel, F. (2005). Can local ecological knowledge contribute to wildlife management? Case studies of migratory birds. *Ecology and Society*, 10(1), 1–12. <https://doi.org/10.1098/rstb.2014.0271>
- Gupta, A. (2007). *Going to school in South Asia*. (G. P. Group, Ed.). Greenwood Publishing Group.
- Hansen, J.W. (2002). Realizing the potential benefits of climate prediction to agriculture: Issues, approaches, challenges. *Agricultural Systems*, 74 (3), 309–330. [https://doi.org/10.1016/S0308-521X\(02\)00043-4](https://doi.org/10.1016/S0308-521X(02)00043-4)
- Heckman, J. (1979). Sample specification bias as a selection error. *Econometrica*, 47(1), 153–162. <https://doi.org/10.2307/1912352>
- Hiwasaki, L., Luna, E., & Shaw, R. (2014). Process for integrating local and indigenous knowledge with science for hydro-meteorological disaster risk reduction and climate change adaptation in coastal and small island communities. *The International Journal of Disaster Risk Reduction*, 10, 15–27. <https://doi.org/10.1016/j.ijdrr.2014.07.007>
- Hotelling, H. (1947). The Economics of Public Recreation. The Prewitt Report, National Parks Service. Washington, DC, USA.
- Huntington, H.P. (2000). Using traditional ecological knowledge in science: Methods and applications. *Ecological Applications*, 10(5), 1270–1274. [https://doi.org/10.1890/1051-0761\(2000\)010\[1270:UTEKIS\]2.0.CO;2](https://doi.org/10.1890/1051-0761(2000)010[1270:UTEKIS]2.0.CO;2)
- Ingram, K.T., Roncoli, M.C., & Kirshen, P.H. (2002). Opportunities and constraints for farmers of West Africa to use seasonal precipitation forecasts with Burkina Faso as a case study. *Agricultural Systems*, 74 (3), 331–349. [https://doi.org/10.1016/S0308-521X\(02\)00044-6](https://doi.org/10.1016/S0308-521X(02)00044-6)
- INSAE. (2015). Enquête Modulaire Intégrée sur les Conditions de Vie des ménages 2ème Edition (EMICoV-Suivi 2015): Note sur la pauvreté au Bénin en 2015. Cotonou, Benin.
- Joshua, R., Dominic, M., Doreen, T., & Elias, R. (2012). Weather forecasting and indigenous knowledge systems in Chimanimani District of Manicaland, Zimbabwe. *Journal of Emerging Trends in Educational Research and Policy Studies*, 3(4), 561–566. <https://hdl.handle.net/10520/EJC126539>
- Kalanda-Joshua, M., Ngongondo, C., Chipeta, L., & Mpembeka, F. (2011). Integrating indigenous knowledge with conventional science: Enhancing localised climate and weather forecasts in Nessa, Mulanje, Malawi. *Physics and Chemistry of the Earth*, 36(14–15), 996–1003. <https://doi.org/10.1016/j.pce.2011.08.001>
- Meza, F.J., Hansen, J.W., & Osgood, D. (2008). Economic value of seasonal climate forecasts for agriculture: Review of Ex-ante assessments and recommendations for future research. *Journal of Applied Meteorology and Climatology*, 47(5), 1269–1286. <https://doi.org/10.1175/2007JAMC1540.1>
- Nkuba, M.R., Chanda, R., Mmopelwa, G., Mangheni, M.N., Lesolle, D., & Kato, E. (2020). Indigenous knowledge systems and indicators of rain: Evidence from rwenzori region, Western Uganda. *Weather, Climate, and Society*, 12(2), 213–234. <https://doi.org/10.1175/WCAS-D-19-0027.1>
- Orlove, B., Roncoli, C., Kabugo, M., & Majugu, A. (2010). Indigenous climate knowledge in southern Uganda: The multiple components of a dynamic regional system. *Climatic Change*, 100(2), 243–265. <https://doi.org/10.1007/s10584-009-9586-2>
- Radeny, M., Desalegn, A., Mubiru, D., Kyazze, F., Mahoo, H., Recha, J., Kimeli, P., & Solomon, D. (2019). Indigenous knowledge for seasonal weather and climate forecasting across East Africa. *Climatic Change*, 156(4), 509–526. <https://doi.org/10.1007/s10584-019-02476-9>
- Rivero-Romero, A.D., Moreno-Calles, A.I., Casas, A., Castillo, A., & Camou-Guerrero, A. (2016). Traditional climate knowledge: A case study in a peasant community of Tlaxcala, Mexico. *Journal of Ethnobiology and Ethnomedicine*, 12(33), 1–11. <https://doi.org/10.1186/s13002-016-0105-z>
- Roncoli, C., Ingram, K., & Kirshen, P. (2002). Reading the rains: Local knowledge and rainfall forecasting in Burkina Faso. *Society and*

- Natural Resources*, 15(5), 409–427. <https://doi.org/10.1080/08941920252866774>
- Roncoli, C., Jost, C., Kirshen, P., Sanon, M., Ingram, K.T., Woodin, M., Somé, L., Ouattara, F., Sanfo, B.J., Sia, C., Yaka, P., & Hoogenboom, G. (2009). From accessing to assessing forecasts: An End-to-end study of participatory climate forecast dissemination in Burkina Faso (West Africa). *Climatic Change*, 92(3-4), 433–460. <https://doi.org/10.1007/s10584-008-9445-6>
- Roudier, P., Muller, B., d'Aquino, P., Roncoli, C., Soumaré, M.A., Batté, L., & Sultan, B. (2014). The role of climate forecasts in smallholder agriculture: Lessons from participatory research in two communities in Senegal. *Climate Risk Management*, 2, 42–55. <https://doi.org/10.1016/j.crm.2014.02.001>
- Speranza, C.I., Kiteme, B., Ambenje, P., Wiesmann, U., & Makali, S. (2010). Indigenous knowledge related to climate variability and change: Insights from droughts in semi-arid areas of former Makueni District, Kenya. *Climatic Change*, 100(2), 295–315. <https://doi.org/10.1007/s10584-009-9713-0>
- Sultan, B., Barbier, B., Fortilus, J., Mbaye, S.M., & Leclerc, G. (2010). Estimating the potential economic value of seasonal forecasts in West Africa: A long-term Ex-Ante Assessment in Senegal. *Weather, Climate, and Society*, 2(1), 69–87. <https://doi.org/10.1175/2009WCAS1022.1>
- Tume, S.J.P., Kimengsi, J.N., & Fogwe, Z.N. (2019). Indigenous knowledge and farmer perceptions of climate and ecological changes in the bamenda highlands of Cameroon: Insights from the bui plateau. *Climate*, 7. <https://doi.org/10.3390/cli7120138>
- United Nations Educational, Scientific and Cultural Organization (UNESCO). (2017). What is Local and Indigenous Knowledge?. <http://www.unesco.org/new/en/natural-sciences/priority-areas/links/related-information/what-is-local-and-indigenous-knowledge>
- Vogel, C. (2000). Usable science: An assessment of long-term seasonal forecasts among farmers in Rural areas of South Africa. *South African Geographical Journal*, 82(2), 107–116. <https://doi.org/10.1080/03736245.2000.9713700>
- WMO. (2015). *Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services*. WMO Technical report N° 1153. World Meteorological Organization.
- Ziervogel, G., & Calder, R. (2003). Climate variability and rural livelihoods: Assessing the impact of seasonal climate forecasts in Lesotho. *Area*, 35(4), 403–417. <https://doi.org/10.1111/j.0004-0894.2003.00190.x>