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Farmers' Demand for Climate Information Services: A Systematic Review

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Abstract: The importance of climate information services (CIS) for farm decision-making is known worldwide. Its use is widely recommended by academics, governments, and development partners, especially in Africa. However, the supply of commercial CIS in Africa remains very low. Considering that the commercial CIS suppliers are business-oriented, the lack of supply is mainly due to the lack of evidence on the demand for it. The specific objectives of the review were to assess the demand for CIS, the key characteristics of the demanded CIS. and the key drivers for the demand for CIS in the Economic Community of West African States (ECOWAS). Through a systematic review, 123 articles were identified on the SCOPUS and Google Scholar databases and 52 papers were included in the study. The models of assessment done by the majority of authors were a simple description based on needs assessments and econometrics modelling to identify the key drivers. The results show that 68% of the farmers in ECOWAS demanded CIS. The average willingness to pay for CIS is estimated to be USD 2.01 for daily forecasts. The usability of CIS, daily forecasts and geolocalized CIS, and customized CIS are the key characteristics farmers are looking for in the ECOWAS region. The main drivers of CIS demand are price, income, vulnerability to climate variability, beliefs and religion, complementary services, gender, type of crops, and farm size. According to the consumer theory, information such as elasticity of price and income, ranked substitutes of CIS, which are still lacking, are key for understanding the CIS demand. However, the review showed that little research work has been conducted in this area. The review also shows the importance of determining among which type of goods CIS should be classified. Knowing whether CIS is a necessity good is vital for suppliers' decision-making.

Keywords: climate information services; demand; systematic literature review; ECOWAS

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1. Introduction

By 2050, Africa's population will reach 2.5 billion [1]. The associated food demand for this population will double; thus, it will be the leading cause of food insecurity and famine across the continent [2]. The appropriate response to this future food demand is to produce more food. Given that more than 80% of African agriculture remains rainfed, there is no hope that Africa can feed itself by 2050 without an immediate response strategy to cope with climate variability [3]. The question is, how can Africa deal with the climate variability?

According to [4,5], this requires accurate, adequate, and timely farm-level information on climate variability. The weather forecast has been an approach through which farmers get to know and understand how farm decision-making can respond to natural occurrences [6]. It has therefore been established that climate information services (CIS) can be an integral input in farm decision-making because of its potential of reducing risks in agriculture that can threaten agricultural livelihoods [7–10].

Therefore, the use of CIS has become an adaptive strategy for farmers [11,12] because the indigenous knowledge through the use of some indicators from trees, birds, stars, and ants' movement is not effective everywhere [13–15]. Even if this combination of CIS and indigenous knowledge is possible, it requires a lot of work and many years of research to come out with usable forecasts [16,17]. The urgency of the situation recommends the use of CIS to support farmers in their decision-making because it can be directly on mobile phones with geolocalization options; it is more reliable and reproducible than the indigenous forecasts [18–21].

The problem is that the supply of CIS remains very low in sub-Saharan Africa (SSA) [22,23]. According to [19–24], the lack of reliable historical observations both to understand the current climate and to evaluate climate models is the bottleneck of CIS uptake in SSA. The coarse-scale of future climate projections, some social and economic barriers including socio-cognitive constraints, and a disconnect between users and producers of CIS are the second group of constraints for CIS uptake [19,25,26]. Moreover, inadequate institutional capacity for effective delivery of CIS [27] is another hindrance to CIS adoption in SSA.

All these reasons explain the current use of indigenous weather forecasts despite a revolution in CIS [13,15,28]. Given all these challenges, one of the solutions is the use of commercial CIS suppliers besides the national agrometeorological offices. However, only commercial CIS suppliers (Esoko in Ghana, Ignitia in Mali and Burkina Faso) are serving in all ECOWAS [29]. The question that comes to mind is, why is there a low supply of CIS in ECOWAS? Is it a lack of demand? A critical analysis of these issues raises the following questions:

1. What is the current level of climate information services demand in West Africa?
2. What are the characteristics of climate information services demanded by farmers?
3. What are the key drivers of demand for climate information services?

The main objective of the study is to assess farmers' weather forecast demand in west Africa.

Specifically, the study aims at:

1. determining the proportion of farmers demanding climate information services;
2. identifying the characteristics of climate information services demanded by farmers; and
3. identifying the key drivers of the farmers' climate information services demand.

The outcomes of this study are useful at ECOWAS and even continental levels. It is also relevant for CIS suppliers. At ECOWAS level, the study contributes to providing more evidence for policy-makers (https://african.business/2022/04/apo-newsfeed/validation-of-the-ecowas-regional-climate-strategy-the-fifteen-member-states-united-for-a-solidary-and-coordinated-action-against-climate-change/ (accessed on 22 June 2022)) on the necessity of supporting climate information services (CIS) delivery to farmers, given that this region is mainly an agri-based economy. At continental level, the study contributes to the African Strategy (https://amcomet.wmo.int/sites/default/files/field/doc/pages/amcomet-integrated-african-strategy-meteorology-13677_en.pdf (accessed on 22 June 2022)) on Meteorology especially in its Strategic Pillar 2 "Enhance the Production and Delivery of Weather and Climate Services for Sustainable Development". Moreover, the study contributes to the African Union's Agenda 2063 Goals specifically on "Environmentally sustainable and climate resilient economies and communities" through its Agenda (https://au.int/ar/node/35000 (accessed on 22 June 2022)) 2063 Priority Areas on the "Climate resilience and natural disasters preparedness". At global level, this study contributes to Sustainable Development Goal (https://www.globalgoals.org/goals/13-climate-action/?gclid=EAIaIQobChMImJ-f9v_D-AIVGNtRCh0dYARGEAAYAiAAEgIkTfD_BwE (accessed on 22 June 2022))-13 particularly in its goal: "Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning".

2. Methodology

2.1. Conceptual Issues

Climate Information Services (CIS)

"Climate Information Services is a decision-making tool derived from climate information that assists individuals and organizations in society to make an improved ex-ante decision" [30]. In addition, climate information services "cover[s] the transformation of climate-related data—together with other relevant information—into customized products such as projections, forecasts, information, trends, economic analysis, assessments (including technology assessment), counselling on best practices development and evaluation of solutions and any other services about climate that may be used for the society at large" [31]. Climate information prepares users for what they will experience in the future [30]. Climate information services also denote the timely production, translation, delivery, and use of climate information to enhance [28]. CIS is the pack of information on the weather delivered to the users [32]. Climate services are, therefore, critical for farm planning, since crop and animal production in most parts of Africa depend on climatic variables [28]. Climate services in recent times are expected to have a market value to end-users [33].

Climate information services focus mostly on the weather forecasts which are useful immediately to users in the short term. The forecasts refer to the prediction of the weather. It can be daily, 10-day forecasts, or even seasonal forecasts. Weather refers to the state of the atmosphere, describing for example the degree to which it is hot or cold, wet or dry, calm or stormy, clear or cloudy, etc. Weather refers to day-to-day temperature and precipitation activity, whereas climate is the term for averaging atmospheric conditions over longer periods. Weather forecast information is critical for communicating knowledge about current and future weather risks to enhance farm-level decisions [32]. A weather forecast is a prediction of the daily variation in the elements of the weather such as rainfall, temperature, and wind [34].

A recent development in the weather forecast is the use of technology to predict weather variability. In most countries within the sub-region, both government and private institutions play this role by trying to provide weather forecasts, especially the extreme events that are needed for decision-making [24]. Weather forecast information includes the onset date of main rains, amount of rainfall, cessation date of the main rains, the temporal and spatial distribution of the main rains, as well as timing and frequency of active dry periods [35]. The forecast information, such as rainfall amount and distribution, is needed to determine when and how much fertilizer to apply; wind speed and direction is needed for spraying weedicides and pesticides; and rainfall cessation and temperature is needed information for harvesting [36]. Weather forecasting is, therefore, considered as a key for agricultural development because of its potential in improving farmers' resilience.

Climate information is synonymous with climate service and hence encompasses all information relating to the seasonal variation of the elements of climate such as rainfall, temperature, and wind [37]. Some institutions in different parts of the world can report climatic conditions that are relevant for decision-making. Moreover, the approach to the provision of such information could be scientific or the use of indigenous knowledge [28]. This makes climate information a little bit varied from the understanding of weather forecast since the latter refers to the scientific reporting and the former is the message irrespective of the methodology used in reporting it.

Another view of climate information according to [8] is the context or message that is being delivered to end-users on climatic conditions and the level of legitimacy and credibility of the message is what will inform its need. Therefore, weather and climate information delivery are the key factors in all agriculture policy discussions [38]. The Food and Agricultural Organization (FAO) indicates that climate information comprises weather forecasting, seasonal climate forecasting, climate change projections, agrometeorological crop monitoring, and agrometeorological advisors. According to [9–65], the scientific forecasts can be packaged in ways that include different kinds of information, across scales and sectors. Such a package can be meaningful and hence inform decisions, especially in the farm sector. The recent academic debate is now on consumer need for the scientific weather forecast information.

2.2. Search Strategy

To answer our research questions on demand, characteristics, and drivers, the strategy was designed to capture relevant papers from the SCOPUS database. To do so, some keywords derived from the research questions were defined. SCOPUS and Google Scholar were targeted as the most complete bibliographic databases that cover scholarly literature from almost any discipline. Three different combinations of keywords were used in the search strategy. The search process used the following keywords in the title: *("Climate services" AND demand AND agriculture) OR ("Weather forecast" AND demand AND agriculture) OR ("Climate information" AND demand AND agriculture)*. However, with these keywords, the results were not fruitful. The final formula used to extract the records was *TITLE ("Climate information" OR "Climate service" OR "weather forecast") AND (agriculture) AND SUBJAREA (busi OR deci OR econ OR soci)*. With this strategy, 123 records were identified from SCOPUS and Google Scholar databases. For reporting, the PRISMA framework, which comprises mainly four stages including identification, screening, eligibility, and included papers [39], was used. We used criteria (described in Table 1) to select the relevant papers for analysis among the 123 papers identified (Supplementary Materials).

Table 1. Inclusion and exclusion criteria.

Criteria	Inclusion	Exclusion
Research articles and reviews	Articles and reviews	Conference papers; articles processing; government reports, project reports
Language	English and French articles and reviews	Non- English and non-French articles
Year of publication	2013–2022	Before 2013
Countries	Articles and reviews from ECOWAS (https://ecowas.int/?page_id=381 (accessed on 22 June 2022)). In order to detect where the studies were carried out, we assessed the methodology section and sometimes, this information is located in the title of the paper.	Non-ECOWAS articles and reviews
Fields	The selected fields were social science, agricultural science, business economics, and econometrics.	Any field different from the selected one

Applying the criteria described in Table 1 to the 123 identified records, 52 papers were considered to be relevant for the objectives of the review (Figure 1). A critical observation of the development of papers shows that the number of papers published on CIS has increased from 2014 to 2020. It reached a maximum of 14 in 2020 (Figure 1). However, a declining trend was observed from 2020 to 2022. This can limit the amount of information generated on CIS available for farm-level decision-making.

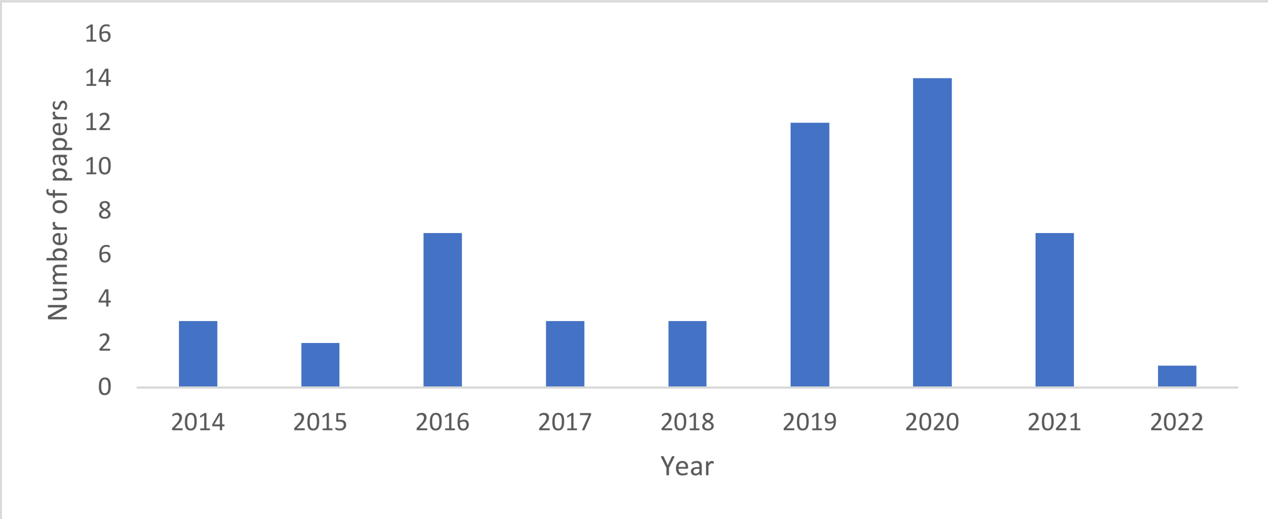

Figure 1. Records distribution from 2013 to 2022 in ECOWAS.

The publications also vary by country (Figure 2). Senegal and Ghana are the leading countries when it comes to the number of studies on CIS in ECOWAS. From the graph below, the Sahelian countries such as Burkina Faso, Mali, and Niger seem to be less productive even though they face more droughts, floods, and climate variability effects.

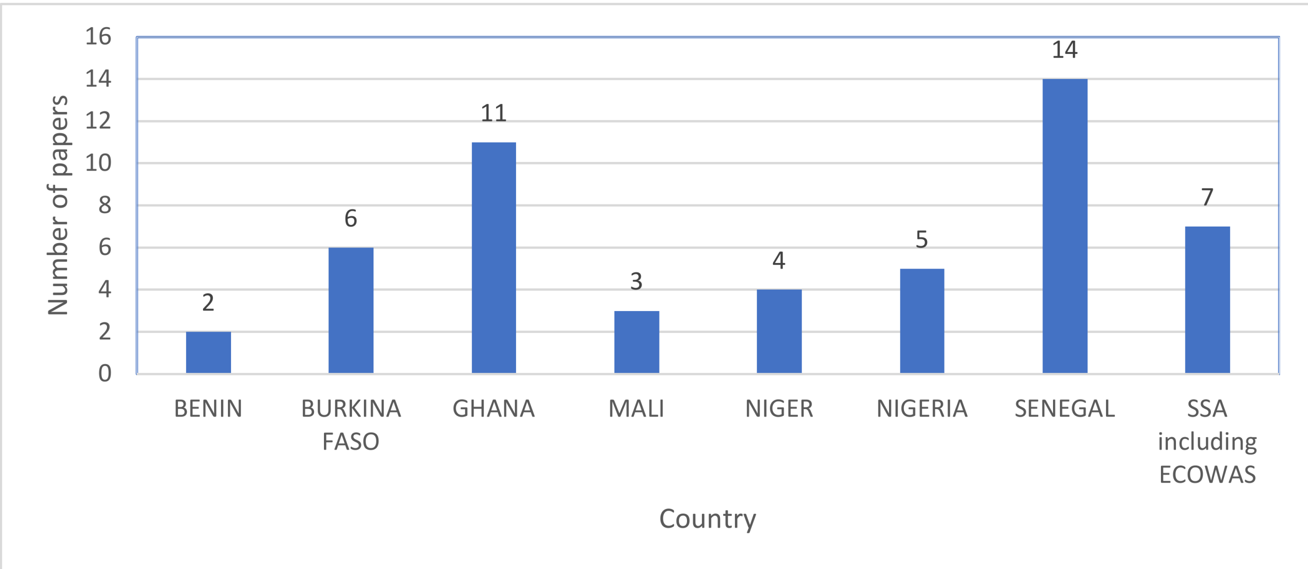

Figure 2. Distribution of papers per ECOWAS countries from 2013 to 2022.

Senegal and Ghana, which are leading producers of CIS literature in ECOWAS, are found along the coast while Benin, Mali, and Niger, which attract less CIS literature, are found in the desert. It was expected that such countries (Mali and Niger) should have attracted more scholarly work on CIS because of their location in arid regions that are prone to the adverse effects of climate variability. Several other west African countries do not attract scholarly works on climate information service demand at all. The existing empirical literature, therefore, lacks analysis of the variation in the supply of CIS by countries within west Africa.

The PRISMA flow diagram for systematic review (Figure 3) were used to map out the number of papers identified, the included and the excluded papers and the reasons for exclusions of those papers.

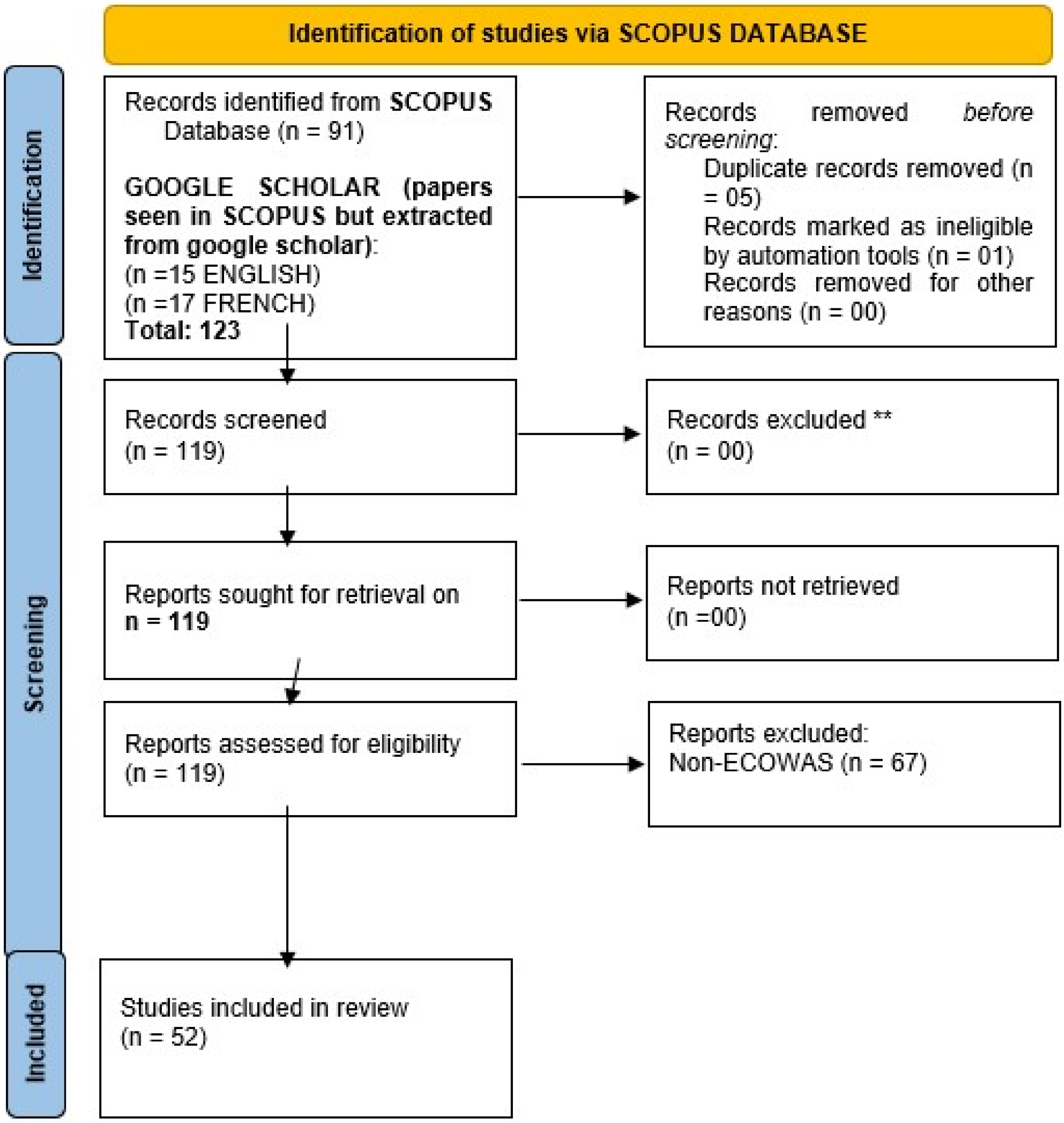

Figure 3. PRISMA flow diagram for systematic reviews adapted [40]. ** If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.

Before further analysis, the review was registered on the Research Registry platform through the following link: https://researchregistry.knack.com/research-registry#home/addregistration (accessed on 22 June 2022). The registration number is researchregistry8028.

2.3. Theories and Methods Used in Identified Records

For each study objective, the proportion (%) of the grand total was calculated based on the fact the paper provides a response to the item. This calculation allowed us to have the weight of each item with respect to the number of items per objective. With these simple statistics, ten types of theories were used (Table 2). Demand for CIS is often analyzed using utility theory and sometimes adoption theory, as indicated by the relative percentages in Table 2. In business economics, the theory of utility is considered to be appropriate in the analysis of consumer demand. In addition, the types of CIS demand have been analyzed in the literature using accessibility theory and needs assessment theory. The needs assessment theory is more adequate in the analysis of the types of CIS demanded by farmers. The key drivers for CIS demand have been identified and analyzed using utility theory. Of course, farmers are driven by the utility of CIS and its impacts, making it the most used theory among the selected papers.

Table 2. Theories used in identified records.

Theory	To Determine the Proportion of Farmers Demanding Climate Information Services	To Identify the Characteristics of Climate Information Services Demanded by Farmers	To Identify the Key Drivers of the Farmers' Climate Information Services Demand
Essential Asset Theory	10.00%	0.00%	0.00%
Accessibility Theory	10.00%	30.00%	0.00%
Adoption Theory	20.00%	0.00%	3.57%
Co-Production Theory	0.00%	10.00%	0.00%
Demand and Supply Theory	10.00%	0.00%	3.57%
Development Theory	0.00%	10.00%	21.43%
Impact Theory	0.00%	0.00%	14.29%
Needs Assessment Theory	10.00%	30.00%	3.57%
Probability Theory	0.00%	20.00%	0.00%
Risk Theory	0.00%	0.00%	7.14%
Social Network Theory	0.00%	0.00%	7.14%
Social Theory	0.00%	0.00%	7.14%
Theory of Broadcast	0.00%	0.00%	3.57%
Theory of Indigenous Knowledge	10.00%	0.00%	3.57%
Theory of Institutional Design	0.00%	0.00%	3.57%
Theory of Insurance	0.00%	0.00%	10.71%
Utility Theory	30.00%	0.00%	10.71%
Grand Total	**100.00%**	**100.00%**	**100.00%**

Source: Authors' construction from the records.

As well as the theories, the methods used for data analysis matter. The demand for CIS is often analyzed using willingness to pay (Table 3). This method is judged appropriate because it helps researchers in detecting if farmers need CIS and then if they are willing to pay for it. The amount can be non-realistic, but to some extent, it gives a clear idea of the demand. Needs assessment is the most used method in the papers investigating the characteristics of CIS demanded. It is followed jointly by the participatory approach and integrated probability forecast model. Bivariate probit modeling is the most used to detect the drivers of CIS demand.

Quantitative and qualitative data were used for studies analyzing demand for CIS (Table 4). For CIS characteristics identification, researchers used three types of methods: mixed, qualitative, and quantitative.

Non-probabilistic sampling is more used (63%) for CIS demand while non-probabilistic sampling is widely used for CIS characteristics identification (Table 5).

Table 3. Methods used in identified records.

Methods	Determining the Proportion of Farmers Demanding Climate Information Services	Identifying the Characteristics of Climate Information Services Demanded by Farmers	Identifying the Key Drivers of the Farmers' Climate Information Services Demand
Average Treatment Effect Model	9.09%	0.00%	0.00%
Bivariate Probit Model	0.00%	0.00%	6.67%
Cis Assessment	0.00%	0.00%	3.33%
Comparative Analysis	0.00%	0.00%	6.67%
Core And Periphery	0.00%	0.00%	3.33%
Criteria	9.09%	0.00%	0.00%
Criteria-Based Evaluation	0.00%	9.09%	0.00%
Gap Analysis	0.00%	0.00%	3.33%
Generalized Discrimination Score (GDS)	9.09%	0.00%	0.00%
Heckman Probit Model	0.00%	0.00%	3.33%
Impact Assessment of Programme	0.00%	0.00%	3.33%
Integrated Probability Forecast Model	0.00%	18.18%	0.00%
Market Assessment	0.00%	0.00%	3.33%
Multiple Evidence Base (MEB)	0.00%	0.00%	3.33%
Multivariate Regression Model	9.09%	0.00%	0.00%
Needs Assessment	0.00%	27.27%	3.33%
Network Analysis	0.00%	9.09%	13.33%
OLS	0.00%	0.00%	3.33%
Ordinal Logistic Regression	0.00%	0.00%	3.33%
Participatory Approach	0.00%	18.18%	0.00%
PCA	9.09%	0.00%	0.00%
Policy Analysis	0.00%	0.00%	3.33%
Probit Model	9.09%	0.00%	3.33%
Programme Evaluation	0.00%	0.00%	13.33%
Propensity To Use	9.09%	0.00%	0.00%
Review	9.09%	9.09%	10.00%
Risk Analysis	0.00%	0.00%	3.33%
Scoring Model	0.00%	0.00%	3.33%
Stocktaking For National Adaptation Planning	0.00%	0.00%	3.33%
Thematic Content Analysis (TCA)	9.09%	0.00%	0.00%
Two Probit Regressions	0.00%	9.09%	0.00%
WTP	18.18%	0.00%	0.00%
Grand Total	**100.00%**	**100.00%**	**100.00%**

Table 4. Type of data used per objective.

Objectives	Mixed	Qualitative	Quantitative	Grand Total
To determine the proportion of farmers demanding climate information services	0.00%	36.36%	63.64%	100.00%
To identify the characteristics of climate information services demanded by farmers	9.09%	54.55%	36.36%	100.00%
To identify the key drivers of the farmers' climate information services demand	6.67%	63.33%	30.00%	100.00%
Grand Total	**5.77%**	**55.77%**	**38.46%**	**100.00%**

Table 5. Sampling strategy used in identified records per objectives.

Objectives	Non-Probabilistic	Probabilistic	Grand Total
To determine the proportion of farmers demanding climate information services	36.36%	63.64%	100.00%
To identify the key drivers of the farmers' climate information services demand	73.33%	26.67%	100.00%
To identify the characteristics of climate information services demanded by farmers	72.73%	27.27%	100.00%
Grand Total	**65.38%**	**34.62%**	**100.00%**

3. Results and Discussion

3.1. Farmers' Demand for Climate Information Services

According to [25], 52% of farmers need CIS in Ghana. A similar study in Burkina Faso carried out by [10] reported that 63% of farmers are willing to pay for climate information services. In Senegal, Diouf et al. (2020) observed that 90% of their study respondents checked weather forecasts before going to fish. This means that, on average, 68% of ECOWAS farmers are demanding climate information services.

This analysis on one hand provides evidence that farmers in some parts of west African countries need climate information services for their farm planning. On the other hand, demand for climate information from formal service providers could be said to be low; some farmers still rely on indigenous sources for their climate information needs [37]. Some key responses to this behavior have been given in the literature. According to [28], farmers are misled by inaccurate scientific forecasts and their inability to comprehend how some activities contribute to climate change. In the view of [42], the various seasonal forecast has limited value because they are not understood by end-users and more especially not provided at the time they are needed. In Nigeria, most farmers' trust in seasonal forecasts has dwindled because they suffered losses when previously relying on the seasonal forecasts for planting [28]. These reasons influence farmers to switch to indigenous climate services, thus reducing the effective demand for the scientific forecast.

Further analysis of farmers' need of CIS was done by taking into consideration the sources of production. The analysis classified farmers into three different groups based on their needs. The first group of papers focus on CIS needs, co-production, and preferences [43–45]. Of course, needs assessment and co-production of CIS contribute to design convenience and usable products. However, this way is not sufficient to ensure demand when farmers cannot afford it. Moreover, needs do not imply the real demand of CIS. Considering the basic law of demand (preferences), pricing, change in income, the existence of substitute products, and complementary products are key components to detect the existence of real demand.

The second group of papers tried to find out the usability, the use, adoption, and barriers to CIS uptake [32,46–48]. This group of papers shows that the use of CIS is very low due to factors such as inaccuracy, low reliability, illiteracy, gender, inadequate targeting of customers, and lack of supportive infrastructures, funding, and institutions. These aspects are key for CIS use; however, some components such as the importance of CIS for farmers still need deepening. It can be concluded that if farmers consider CIS as a necessary good such as fertilizers and seeds, their perception may change.

The third group of existing papers deal with the impact side of CIS through implemented programs run by NGOs, projects, governments, and research centers [24,30,49]. By providing the potential benefits of using CIS, the farmers can be more aware of its utility and thus adopt it in their farming businesses. These results help users to decide if the CIS can make difference in their farming, but the suppliers still lack some key information to supply CIS.

3.2. Characteristics of CIS Demanded by Farmers

This section analyzes the characteristics of CIS demanded by farmers. The results show that reliability of the forecasts, daily forecasts and geolocalized CIS, and usability of CIS are the key features (see Table 6) when it comes to CIS production for farmers in west Africa. Specifically, the daily forecasts feature is important to farmers as observed by [10–25]. The other features and types of CIS comprise reliability, tailoring, and a combination of indigenous and scientific forecasts.

Table 6. Characteristics of CIS needed by farmers.

Characteristics of CIS Need	Proportion (%)
Reliability of the forecasts	18.18%
Daily forecasts and Geolocalized CIS	15.15%
Usability of CIS	12.12%
Impactful CIS	9.09%
Tailored CIS	9.09%
Daily Integrated Probability Forecasting (IPF)	6.06%
Availability of CIS	3.03%
Change of rain and Intensity of rain	3.03%
CIS comprises a full package of rural activities	3.03%
CIS for Cash crops	3.03%
CIS SMS delivery	3.03%
During growing season	3.03%
Geolocalized CIS	3.03%
Rainfall onset date	3.03%
Seasonal climate forecast (SCF)	3.03%
Wind direction	3.03%
Grand Total	**100.00%**

Specific daily forecast needs of CIS include rainfall distribution and amount to determine how much fertilizer to apply on the field, and wind direction and speed for spraying of weedicides [36]. In Ghana, farmers expressed interest in the seasonal forecast to determine sowing periods at the right time and avoid considerable losses [34]. In Nigeria, farmers seek daily forecast information on all phases of planting operations. This means that CIS with single variables will not address the needs of users. Ref. [8] observed that in Senegal, women expect seasonal forecasts to come along with seasonal commodities prices variation. This helps them purchase the maximum quantity of inputs such as seeds that will be appropriate for the season.

Further crosstabulations were generated on the types of CIS demand by country. The results (see Table 7) show that reliability is crucial for farmers in Ghana, Niger, and Senegal [42] while the usability of CIS is important for Burkina Faso, Nigeria, and Senegal [8–50]. In some countries such as Ghana and Senegal, daily forecasts and geolocalized CIS is expected by farmers [34–51]. According to [52], Malian farmers are now using daily rainfall forecasts from a program called "Sandji" to adjust their farm and non-farm activities. The daily rainfall forecasts allow farmers to reschedule appropriately the day after getting the prediction.

Table 7. Characteristics of CIS needed by the country.

Row Labels	BURKINA FASO	GHANA	MALI	NIGER	NIGERIA	SENEGAL	SSA Including ECOWAS	Grand Total
Availability of CIS	0%	0%	0%	0%	100%	0%	0%	100%
Change of rainfall and its Intensity	0%	100%	0%	0%	0%	0%	0%	100%
CIS comprises a full package of rural activities	0%	0%	0%	0%	0%	100%	0%	100%
CIS for Cash crops	0%	100%	0%	0%	0%	0%	0%	100%
CIS SMS delivery	0%	100%	0%	0%	0%	0%	0%	100%
Daily forecastsGeolocalized CIS	0%	40%	0%	0%	0%	20%	40%	100%
Daily Integrated Probability Forecasting (IPF)	0%	100%	0%	0%	0%	0%	0%	100%
During growing season	0%	100%	0%	0%	0%	0%	0%	100%
Geolocalized CIS	0%	100%	0%	0%	0%	0%	0%	100%
Impactful CIS	33%	0%	0%	0%	0%	33%	33%	100%
Rainfall onset date	0%	0%	0%	0%	100%	0%	0%	100%
Reliability of the forecasts	0%	33%	0%	17%	33%	17%	0%	100%
Seasonal climate forecast (SCF)	100%	0%	0%	0%	0%	0%	0%	100%
Tailored CIS	0%	0%	33%	0%	0%	33%	33%	100%
Usability of CIS	25%	0%	0%	0%	25%	25%	25%	100%
Wind direction	0%	0%	0%	0%	0%	100%	0%	100%
Grand Total	**9%**	**33%**	**3%**	**3%**	**15%**	**21%**	**15%**	**100%**

3.3. Key Drivers of the Farmers' Climate Information Services Demand

The findings from the 52 papers included in the study showed that the drivers of CIS demand can be classified into 14 categories. Among the drivers of CIS demand, vulnerability to climate variability is the key driver of CIS demand [8,23,63]. When farmers have experienced climate shocks (e.g., droughts and floods), they are more aware of their vulnerability; consequently, they are willing to find some solutions.

For [54], the usability and communication channels (radio, TV, farmers-based organization, churches, mosque) of CIS mattered a lot in their needs assessments. Ref. [46] indicated that mobile phone ownership positively impacts CIS demand. This means that the suppliers should care about which communication can reach the end-users (farmers). Furthermore, if the information is technical, many farmers cannot use it in their farming businesses.

Access to extension services increases CIS demand [7,55,56]. The distance between extension services and farmers can be leveraged to increase CIS demand. Networking with rural institutions can increase CIS use [57]. Policy framework and supportive institutions can increase CIS [21]. The socioeconomic variables of importance are gender, intersection of seniority, religion, and belief, and they positively influence CIS adoption at the household level [7,14,24].

Another key driver of climate service uptake is NGO programs in west Africa. In Burkina Faso for instance, NGOs have included in their program the concept of resilience to help the rural community to face drought, flood, wind, and heat. Considering that Burkina Faso National Agrometeorological agency is facing fundraising and forecasts delivery challenges to end-users, the NGOs started raising funds and share CIS to end-users in 2011 [58]. NGOs also promote climate-smart agriculture technologies (CSA) such as short-cycle seed, use of biochar, soil restoration, water conservation techniques, and crop rotation.

For a thorough assessment of the demand for CIS, certain variables have priority according to the basic economic theory of demand. These are prices, income, substitutes to CIS, and prices of related products. In addition, the question of the nature of the service seems to be important. The analysis of the selected studies shows that these variables, although of vital importance, are not deeply taken into account by empirical analysts.

- **Price for CIS**

From the selected studies, the price of CIS is not known with certainty. For example, 94% of the sample studies were not able to report what price level consumers are willing to pay for CIS. It was discovered that the few studies that examined the price at which users are willing to pay provided different prices for some available CIS. According to [10], Burkinabes are willing to pay 3496 FCFA (6.90 USD) for seasonal climate forecasts, 1066 FCFA (2.13 USD) for 10-day climate forecasts, and 1985 FCFA (3.97 USD) for daily forecasts. According to [38], respondents are willing to pay CIS and the minimum amount is estimated at 0.6 USD for weather forecast information in the Savelugu-Nanton municipality of the northern region of Ghana. In contrast, Ref. [25] found that the majority of farmers in Ghana are not willing to pay for CIS. These results are conflicting and therefore, raising a debate on CIS pricing in Ghana.

The evidence on pricing of CIS is based on willingness to pay in studies. However, such estimates from willingness to pay (WTP) modeling are sometimes unrealistic according to some authors. One key challenge is that the amount one is willing to pay for a commodity or service is not the same as the effective demand. These critiques imply that the amounts derived from WTP should be taken care of by suppliers. Then, a deep assessment of adequate pricing is needed for suppliers to avoid overpricing given the economic context of west Africa. The pricing should consider the type of farmers because cash crop farmers, staple crop farmers, livestock farmers, fishermen, and maybe females and male may be willing to pay differently for CIS. Moreover, what will be the proportion of farmers who will decide to pay for CIS if the current price decreases by 10%? What about if the price increases by 10%? Therefore, price elasticity analysis is required to have a better understanding of west African farmers' response to CIS' price variation.

- **Substitutes to CIS**

From the selected studies, four main substitutes for CIS are identified. The key substitutes among them include farmers' belief in the forecast results, religion, climate-smart agriculture technologies, and indigenous forecast (see Table 8). The belief is detected to influence CIS demand when the farmers do not believe that weather variability can be managed by humans [41]. Such a belief can have a greater impact on demand in different ways. One way could be that farmers who do not believe that weather events can be managed will lack confidence in CIS and hence will not use them. As it is known, belief drives decisions and decisions drive action and behaviors.

Table 8. Substitutes of CIS in ECOWAS countries.

Substitutes	Proportion (%)
Unknown (no clear statement in the study)	50%
Indigenous forecasts	34%
Climate-smart agriculture	6%
Agricultural extension service	3%
Belief	3%
Religion	3%
Grand Total	**100%**

Similarly, religion is perceived to drive CIS demand [14]. Some farmers were found to have the belief that weather events are caused by God and hence the outcome is better predicted by men of God. As a result, they tend to rely more on the gospels than on scientific forecasts of CIS. According to some authors, climate-smart agriculture technologies (CSA) are also used to mitigate climate change effects such as drought with short cycle seed and way of ploughing [38–57]. This means that some farmers resort to the use of CSA practices in place of CIS.

In addition, indigenous forecasts continue to be used by farmers [24,28,36,42]. Such groups of users tend to believe their local conditions can better tell them about climate variability than the scientific forecast.

Though many studies did not highlight the substitutes, CIS suppliers are encouraged to consider these key substitutes as serious competing factors.

Beyond the classic substitutes, agricultural index-based micro-insurance seems to be an alternative for farmers in Sahelian countries. In Niger, for example, farmers are willing to pay for agricultural index-based micro-insurance to protect themselves against climate disasters [59]. A similar observation was made in Burkina Faso, Mali, Senegal, and Côte d'Ivoire. Indeed, many farmers started paying for crop insurance through "PlaNet Guarantee (http://www.planet-guarantee.org/component/content/category/8-la-societe (accessed on 22 June 2022))", a crop insurance firm [60].

- **Complementary services or technologies to CIS**

From the review, some complementary services to CIS were identified. As shown in Table 9, these services include access to credit, the use of the bottom-up approach, the use of appropriate broadcasting channels, climate-smart agriculture (CSA), market access, and market information. Broadcasting channel is seen to be the main complementary product for CIS demand in west Africa [33,37,54,61]. Broadcasting technologies such as radio, TV, Internet access, and mobile network today have greater influence on demand for CIS. These technologies are used to create consumer awareness and hence add value to the services.

Table 9. Complementary products or technologies accompanying the CIS demand.

Complementary Service	Proportion (%)
Access to credit	3%
Bottom-up approach	3%
Broadcasting channel	39%
CSA	3%
Market access	3%
Market information	3%
Unknown	45%
Grand Total	**100%**

The co-production approach is also seen to be an appropriate approach when it comes to CIS demand assessment because it helps to generate the complementary products needed by farmers [28]. The advantage of co-production is that it blends both indigenous and scientific forecasts of CIS. Moreover, farmers consider market access to be a complementary service which should be delivered with CIS [8]. On this, access to market for goods and services will influence farmers' demand for CIS in order to meet the needs of the market. In the same view, market information such as prices of commodities, inputs, prices, and labor cost seem to be complementary products to CIS [9]. Access to credit increases farmers' income, thus, it leads to CIS demand in some countries [7]. However, 45% of the studies that have been reviewed are silent on the complementary services to CIS, thus bringing to the fore the limited scientific information on the drivers of CIS.

Beyond the fact that complementary products are needed by farmers, some authors suggest moving from one service to a package of services where the farmers can access other services (market information, insurance, farm optimization tools). According to [62], climate information service and index insurance should be bound. According to [63], the uptake of CSA remains low because of lack of digital services. They suggest binding CSA, CIS, and even extension service as a package to enhance the uptake of technologies in sub-Saharan Africa [64].

- **Impact of income on CIS demand**

Climate information services are considered an input for farmers. For long-run sustainability, farmers should be able to pay for CIS themselves, thus highlighting the role of farm income in the analysis of demand for CIS. According to [41], income increases will lead to a decrease of CIS demand especially for fishermen in Senegal. However, Refs. [8,25,38] observed a direct relationship between income and demand for CIS. This contradictory literature suggests that income can have a different influence on demand based on different farmer segments, such as in the case of crop farmers in Ghana and fishermen as observed in Senegal. In addition, ref. [25] concluded that access to credit, government subsidies, and access to market used as proxy of income lead to an increase in CIS demand in Ghana. However, the majority of papers are silent on the impact of income variation on CIS demand.

- **Targeting for CIS delivery**

From the selected papers, eight segment of farmers (farmers: commercial, livestock, tree crops farmers, staple crops farmers) can be derived. Most authors considered smallholder farmers as the target [38,50,65]. However, knowing the segment of customers for CIS is crucial for suppliers. Among the studies, fishermen from Senegal check CIS before going to the sea [41]. In Ghana, male farmers demand more CIS than female [14]. Furthermore, [37] observed that in Ghana, rice farmers demand CIS to control water level in the dam. In Mali, staple crops farmers, especially cereals farmers, demand more CIS than other staple crop farmers [8]. In Burkina Faso, livestock farmers use less CIS in their farming system [42]. This highlights the role of farmer segment as an important determinant of demand for CIS in west Africa. In order to meet the farmers' preferences, it is important to have further evidence on each farming type's opinions. For instance, what will be the preferences of staple crops farmers and cash crop farmers for CIS? What will be the preferences of tree crops and livestock farmers for CIS?

4. Conclusions

This paper studied the demand of CIS in west Africa through a systematic literature review procedure. Specifically, the proportion of farmers in need of CIS, the key characteristics of the demanded CIS, and the main drivers of its demand were determined. It is concluded that majority of farmers from the ECOWAS region demand CIS. The characteristics of CIS demanded are mainly the reliability of the forecasts, daily forecasts and geolocalized CIS, and the usability of the CIS. Moreover, farmers who experienced climate shocks perceived CIS to be usable to them. The key drivers of this demand include the effectiveness of communication channels, the access to extension services and NGOs, belief system, actual income, and price of CIS. Furthermore, indigenous forecasts and religion continue to be the substitutes of CIS in this region. In addition, some complementary services including crop insurance, climate-smart-agriculture (CSA) technologies, and market information systems can be supplied jointly with the CIS. While there are some bottlenecks in the supply of CIS including inadequate financing model and poor infrastructure, the demand for CIS is also influenced by farmers' socioeconomics such as income, gender, and enterprise characteristics. It was also noticed that income and price elasticity should be analyzed with respect to farmers' objectives (staple cropping, cash cropping, livestock farming, tree cropping) in future investigations. More in-depth analysis is also needed to determine in which type of good (necessity, luxury, normal, and inferior) the CIS can be classified because of its influence on stakeholders' decision-making strategy.

5. Recommendations

Semi-arid regions in ECOWAS (Burkina Faso, Mali, Senegal, Niger, and northern Ghana) are more vulnerable to climate variability while very few CIS suppliers are currently working in these areas. The main reason for the lack of CIS commercial suppliers is probably the lack of evidence of its demand when we know that they are business-oriented firms. Therefore, farmers' responses to the variation of prices and income should be more closely investigated. More service providers should be encouraged to make offerings. Given that the willingness to pay for CIS remains broad, a deep assessment of elasticity price and income may help in suppliers' decision-making in ECOWAS.

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