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A Decision supporting algorithm for improving sunflower production amidst changing weather in the singida region, Tanzania

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Abstract

Recent drastic weather shifts driven by global warming have adversely affected African agriculture, culminating in low crop yields. The purpose of this study is to design decision support algorithms (DSA) that will aid sunflower farmers in the Singida Region in managing the risks associated with weather variations and consequently improve crop yields. A total of 80 respondents, including meteorologists, agricultural extension officers (AEOs), and farmers with feature and smart phones, contributed to the study's designed and empirical validation of the algorithm. The study designed and validated the DSA that assist sunflower growers in the Singida region in making informed decisions to improve productivity amidst adverse weather changes. As revealed, farmers who use both smartphones and feature phones are extremely satisfied with the DSA functions. The decision support algorithm designed in this study integrates smart and feature phone elements that were overlooked in comparable, prior systems and algorithms. Farmers that grow other crops that behave similarly to sunflower in areas with characteristics comparable to the Singida region will find the study's designed and validated algorithm helpful. In order to assist sunflower farmers in making decisions, the DSA interprets and processes data on a predetermined set of daily activities. In order to advance the use of ICT applications in farming activities, the study's findings took into consideration farmers who used feature phones with SMS-based notifications and those who used smartphones. The existing systems mostly concentrated on integrating web-based systems through mobile phones, which is dependent only on internet connectivity being available. Moreover, the use of web-based systems via mobile phones only results in restricted coverage and is out of reach for many farmers. Thus, the innovative element that emphasizes the study's contribution to the field in Tanzania's rural areas is the integration of feature and smart phone.

Keywords: *ICTs; Decision Support Algorithm; Smart-feature phone; weather changes; Agriculture; Sunflower Productivity*

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Introduction

Agricultural production in Africa is significantly impacted by adverse weather shifts owing to variability (Stevanovi'c *et al.,* 2016). The continent's vulnerability is attributable to several challenges, including extreme poverty, limited employment opportunities, and a lack of sustainable development (Churi *et al.*, 2013; Nhemachena *et al.*, 2020). For instance, it is anticipated that agricultural production in the African region will decrease by 15% to 50% (Nhemachena *et al.*, 2020). Insufficient strategic efforts are geared towards persuading small-scale farmers and others to embrace innovative mitigation strategies (Churi *et al.*, 2013).

Furthermore, there is stagnation in cereal yields in Africa compared to other continents (FAO, 2018 and FAOSTAT, 2017). Additionally, there was a decrease in sunflower yield in Tanzania, mainly in the Singida region, from 1.7 t/ha in the 1986–1987 season to 0.7 t/ha in the 2019–03 season. This was caused by unfavorable weather patterns that led to farmers making poor decisions about when to plant in relation to the status of rainfall (Churi, 2013). Consequently, it is essential to understand weather change mitigation techniques and the factors that farmers take into account when choosing which crop varieties to plant, such as sunflowers, which are widely grown in the Singida region.

Tanzania is one of several countries that cultivate sunflower oilseeds, which are then processed into by-products that are fed to livestock and used as raw materials in the production of cholesterol-free edible cooking oil. Approximately 13% of the world's edible sunflower oil is produced in Tanzania (Tanzania Invest, 2022). Sunflower thrives in the arid climate of the Central Corridor, unlike other crops like maize and wheat. Initiatives are in place to improve sunflower production in Tanzania; for instance, the Tanzania Agricultural Development Bank (TADB) recently issued a TZS 1.3 billion cheque to 458 Agricultural Marketing Co-operative Societies (AMCOS), recognizing the importance of sunflower production in Singida Region sunflower agriculture initiatives (TABD, 2019). Thus, although sunflower oilseed production is widespread across Tanzania, the Singida Region's production is declined due to adverse weather conditions, which require immediate technology to overcome it.

Farmers in Africa, particularly sunflower growers in Tanzania's Singida region, are confronted by the hostile impact of weather variability (Stevanovi'c *et al.*, 2016 and Benedict and Majule, 2015). Weather changes harm various crops including sunflower production due to limited knowledge and appropriate information on which farmers rely when making decisions (Nhenio *et al.*, 2019). While a small number of farmers rely on radio and television stations, the majority, particularly in the Singida region, make farming decisions using conventional and local methods, including indigenous knowledge and intuitive prediction (Nhenio *et al.*, 2019; Churi *et al.*, 2013). Even though these strategies have historically worked, the recent extreme weather change conveys the need for technological innovation. Therefore, designing an algorithm-capturing mobile technology is essential to aid farmers in the Singida region of Tanzania in making decisions, through accessing agricultural information, and sharing decision-making strategies and practices.

To create strategies or policies to achieve their goals, agricultural decision-makers at all levels need an extensive amount of information to better comprehend the implications of their decisions. For instance, it is critical to provide weather forecast information to sunflower farmers to respond to weather changes accordingly and make better agricultural decisions (Nhemachena *et al.*, 2020). Ad hoc seasonal weather forecasts are now issued by several meteorological agencies in the Singida region, which have historically and insufficiently concentrated on a broader coverage of sunflower growers and their specific needs (Churi *et al.*, 2013). ICTs must be employed as a contemporary innovation to improve decision-making among sunflower growers in the Singida region by facilitating knowledge and communication exchange of meteorological information.

In semi-arid regions, information and communication technologies (ICTs) are essential for mitigating the effects of weather variations on agricultural output (Karanja, 2018). For instance, it encourages the diversification of livelihoods and the use of alternative scenarios to assist local decision-making. Additionally, ICT improves the information and knowledge sharing amongst key stakeholders by making climate change-related information more relevant and accessible to local actors (e.g., through Web-based materials created in the local language and addressing local priorities, or through text messages with straightforward, strategic content sent to farmers' cell phones). Thus, studies examining the relationship between ICTs, development, and climate change point to the usefulness of ICT tools like decision support algorithms in addressing weather variations and enhancing agricultural output in semi-arid areas (Ereri, 2020).

Specifically, the application of ICT is to enable sunflower farmers to better share agricultural knowledge and disseminate weather information. Famers have been affected by weather changes Sunflower farmers currently receive information through a range of existing dissemination channels and strategies, including radio, television, in-person conversations, and email (Nhenio *et al.,* 2019), to support their farming decisions. However, these techniques fall short of adequately supporting sunflower farmers to carry out their farming activities effectively and efficiently. The decision support algorithm comparing the predefined set of series of farming activities and the status of rain fetched automatically from weather source including TMA and disseminate information through feature and smart phones own by farmers timely. The use of contemporary and inventive technologies to support interactive communication among agricultural stakeholders has been insufficient (Churi *et al.,* 2013; Nhenio *et al.,* 2019). This study sets out to design an algorithm that supports decision-making to aid sunflower farmers in Tanzania's Singida region practice farming activities efficiently, amidst adverse weather shifts.

Globally, existing algorithms, systems, and models support agricultural sector production and these include the Agricultural Production Systems Simulator (APSIM) Gaydon *et al.,* 2011), the web-based decision support system (Soyemi and Bolaji, 2018), and the Decision Support System for Enhancing Crop Productivity of Smallholder Farmers in Semi-Arid Agriculture in Tanzania (Churi *et al.,* 2013). The primary goal of the current methods is to support agricultural production. However, they face several challenges, such as primarily using SMS to distribute information from weather sources without contextualising it to the daily activities of farmers (Soyemi and Bolaji, 2018). Additionally, the data sets used were not from Tanzania; rather, they originated from other countries such as Bangladesh, and others. Thus, the system or algorithm may not function as envisioned (Soyemi and Bolaji, 2018). Additionally, no offline text was used; hence, the lack of internet access in the majority of developing countries such as Tanzania was not considered (Churi *et al.,* 2013). Therefore, to address the issues raised by the existing systems and algorithms, this study designed the decision support algorithm for sunflower production among farmers in the Singida region.

The decision support algorithm was developed as follows: The researcher examined, identify, and define the study problem using literature studies and agricultural stakeholders' surveys. Requirement elicitation and analysis were done in which user needs were explored in order to implement the requisite DSA and its architecture diagram for a prototype was designed. The DSA complete for implementation, at first was presented to stakeholders including famers, extension officers and matereologistist for judgement and evaluation using the real data collected from TMA. Finally, the results of the validation were considered as a basis for the refining the DSA for final.

Materials and Method

Study Area

The current study was conducted in Tanzania's central region of Singida. The study area was purposely selected because it is the area where sunflowers produced more compared to other regions in Tanzania. Small-scale farmers are the major producers of sunflowers in Singida, and they are the most susceptible to weather variations (Churi, 2013).

Sampling and Sample Size

The study employed nine (9) villages in two districts purposively selected that are prominent in producing sunflowers. This study used a total of 80 respondents as sample size from nine (9) villages. The total sample size of 80 was deemed reasonable for validating the developed decision support algorithm as supported by Tripath *et al.,* (2021). Furthermore, a sample size of 50–80 respondents is advised due to the study's usage of interview techniques to gather opinions for validation; however, the maximum number from the range is appropriate for maintaining the data's validity (Vasileiou *et al.,* 2021).

Eighty respondents were chosen using simple random sampling techniques; of these, 72 were farmers (3 cellphones and 69 feature phone users) who directly use the DSA and took part in its validation; six (6) were extension agents with extensive knowledge of agricultural activities who also contributed to the DSA's design and validation by providing functional requirements; and two (2) were agrometrologists who provided functional requirements related to weather status because they are sufficiently knowledgeable about weather changes. The use of simple random was achieved by selecting respondents from the list in their subgroups established based on probability proportional to size (PPS) using lottery method. Each member of the subgroup was assigned a number using a small piece of paper. These pieces of papers were folded and mixed into a box. Lastly, samples were taken randomly from the box by choosing folded pieces of papers in a random manner. The simple random sampling particularly the lottery method was employed in order to minimize bias from the selection procedure to sample representation. The selection of heterogeneous samples was deemed important because to capture wide information as these are the main stakeholders of sunflower production activities.

Study Design

This study used the design science method for generating solutions to problems, advancing knowledge, evaluating designs, and communicating findings to the right audiences as recommended by Kussul *et al.,* (2022). Prototyping was employed in the system design for this investigation. This methodology enabled the researcher to test the algorithm solution, as some of the user requirements were not well defined. In this study, the following were the processes achieved to accomplish the design and validation of DSA included; problem identification and motivation, specification of the objectives for a solution, design and development, demonstration, evaluation, and communication.

In order to ascertain whether the prototype was a workable solution, it was created in part using DSA and distributed to a small group of users, including AEOs. A few remarks were made, including the need for information to be available online and offline and the suggestion that the DSA expand coverage to include farmers who own smartphones and feature phones. Following their complete participation in a prototype evaluation, end users provided input that improved the acceptability of the system. Ultimately, the decision support algorithm (DSA) was designed with input from end users and was empirically proven in practice.

Ethical consideration

This study followed ethical guidelines by allowing respondents to select whether or not to engage in the study on a voluntary basis. In order to perform this research, a permission letter was also sought from the research directorate. This study took respondents' privacy and confidentiality into consideration. Lastly, permission to gather data was obtained from the village offices, ward offices, and other governing bodies.

Results

This section presents the results of the development of the algorithm for making informed decisions. The results of the decision support algorithm (DSA) design, including the DSA architecture, architectural implementation, decision support, and algorithm evaluation, are also presented in this section.

Proposed DSA Architecture

The designed DSA for boosting sunflower production in the Singida region is graphically represented in Figure 1 below and it operates as follows. Users must first download and save the DSA, which is a web-based application system to their smartphones. When their mobile phone numbers are registered, those without smartphones can communicate with the system by receiving plain text messages sent to them. The web-based system, an API (Application Programming Interface), and a Short Messaging web-based System engine make up the DSA's backend (SMS Engine). The super users are in charge of providing all customers with the necessary information and have access to all resources from the backend through the APP (farmers).

Figure 1

DSA Architecture

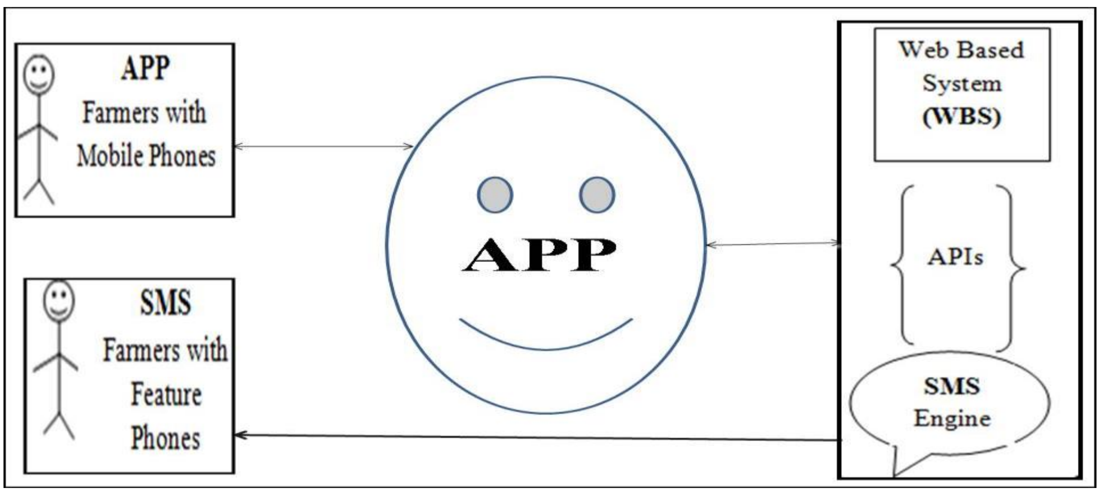
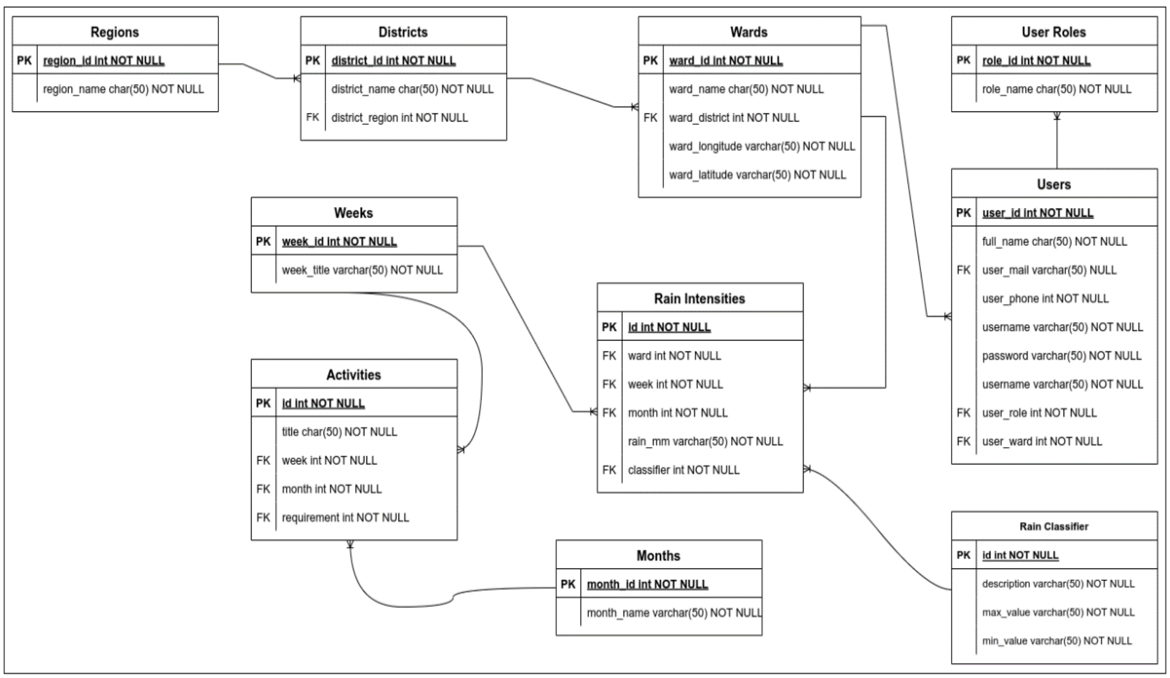


Figure 2 depicts the results of the database, which was designed using the MySQL database management system (DBMS). The database was designed to store both predefined data and rain intensity after classification.

Furthermore, the database captured and stored the predefined data on daily sunflower activities in the Singida region, and information comparisons before dissemination to farmers. A week ID field, for example, is included in the rain intensity entity to provide a mapping between rain intensity and the specific week that the rain will fall. Using this information, farmers forecast when to prepare land, cultivate it, or apply fertilizer. According to this design, if a farmer knows how much rain is expected in a given week, they can request advice about the type of activities they should undertake about the amount of rain. The DSA then compares the two circumstances and determines an appropriate course of action.

Figure 2

Entity Relationship of DSA



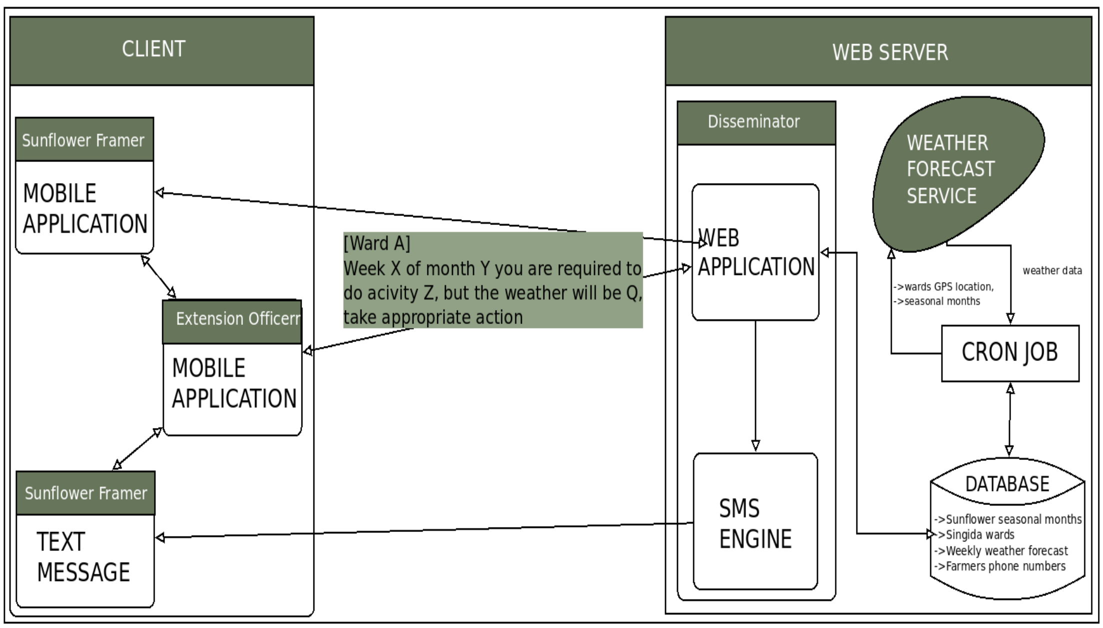
Implementation of the DSA

Another outcome of this research is the DSA implementation architecture (depicted in Figure 3) which is split into two parts namely: the front end and the back end. A client serves as the system's front end, and a web server serves as its back end. Sunflower growers and extension agents use both a text-messaging feature and a mobile application. The farmer can take action on activity Z in week X of the month Y if the favourable weather condition Q is met owing to the system's analytical backend and front-end functions. The second section, namely decision, contains some API queries for reading weather data from various sources including TMA as input to DSA, which is the monthly or weekly rain amount or quantity. This raw data is classified using pre-defined and database-stored criteria. Furthermore, the weather data stored in the database as shown in Figure 2 was compared to the seasonal sunflower activities performed by Singida sunflower farmers, which were also pre-defined and stored in the database. The DSA

compares the amount of rain recorded for a specific ward to the programmed classified amount of rain. The third component is information dissemination (output), in which the second part decision automatically disseminates information about the status of weather.
On the back end (server side), the DSA functions in the following phases: Stage I: The TMA and other sources, including the DSA, are automatically consulted for weather information. Stage II: The DSA categorizes generated data (raw data) using predefined classifiers as low, cloud, moderate, and heavy. Stage III: The system stores the predefined practices for growing sunflowers and the categorized data. The database includes weeding, planting, and land preparation tasks. Stage IV: Comparison and Dissemination; the DSA compares the weather data that has been stored. Proceed through a predetermined series of sunflower cultivation activities before displaying. The app requests this information about a specific ward.

Figure 3

DSA Implementation Architecture



The DSA functions in the following ways on the front end (client side): The program automatically locates the ward when the user launches it. The app searches the database for the ward if it already exists and displays the results. The program prompts the user to select an award from the database's list of awards if the specified ward is not readily available. The software then searches the database, forwards the information, and displays it after receiving the ward name. It should be mentioned that the mobile app matches the stored meteorological data to a predetermined set of sunflower farming operations before providing information to the user upon request (for example, if at ward x, there is minimal rainfall, start field preparation). Users with feature phones who have registered with their numbers and wards receive text messages, as shown in Figure 4, informing them of the appropriate course of action concerning the situation of the rain.

Figure 5 is an illustration of how DSA operates in principle. The decision-making and the registration features are the two primary elements of the devised algorithm as shown in Figure 5.

The registration feature also has two main categories, one for smartphones and the other for feature phone users. Smartphone users have to download the software and launch it by simply typing their Ward's name to begin interacting with it. AEOs use the mobile number and ward name to register users with feature phones.

There are queries for reading ward weather data from multiple sources, including the Tanzania Meteorological Agency (TMA). The weather data includes weekly rainfall anticipated amounts, classified rainfall quantities and the activities to be undertaken depending on the state of the rainfall intensity as shown in Figure 5. The algorithm determines the type of activity to be performed at a specific ward by comparing the quantity of rain observed and classified for a specific ward with the established daily activities, information for use and then subsequent action is conveyed.

Figure 4

Decision Support Algorithm Process

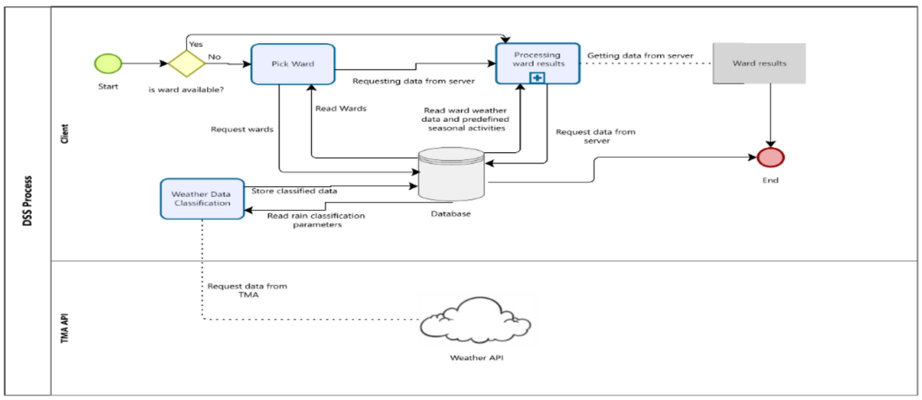
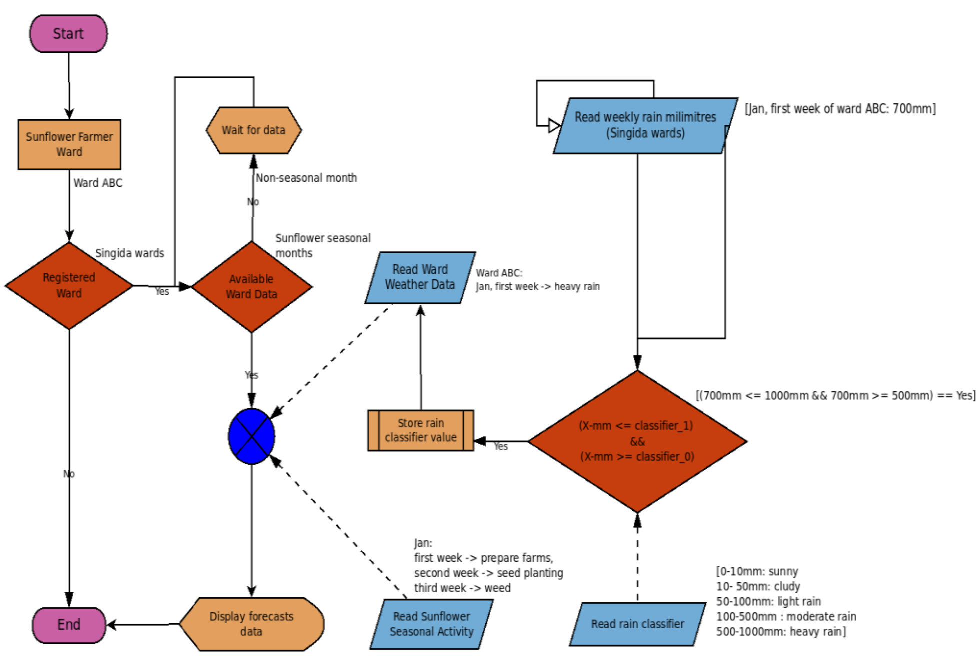


Figure 5

How Decision Support Algorithm Works



DSA Evaluation Results

It was crucial that consumers experienced the newly designed product during this phase and offered input, which enabled the system's improvement. Iterations and modifications based on user feedback during this phase led to a viable product. Involving consumers at every level of product development was one method for promoting the usage of digital technologies. Because users are the main stakeholders in the system, this study used the approach to guarantee both the usability and acceptance of the DSA. The DSA was evaluated by sunflower growers' different wards and was improved according to their usability suggestions.

The mobile app offers user information upon request after matching the stored meteorological data to the present set of sunflowers in a series of farming activities, as the results are shown in Table 1

Table 1

Evaluation results of DSA in relation to rain status in two wards of the Singida

WARD	Receiver Number	Week	Status of Rain	Activity to be done
		1st week -Oct	moderate	No activity
		2nd week-Oct	cloud	Start weeding
		3rd week-Oct	Heavy rain	No activity
		4th week -Oct	Light rain	No activity
		1st week-Nov	Sunny	No activity
Kitenkete	+255713285519	2nd week-Nov	Cloud	Apply fertilizers
		3rd and 4th week-Nov	Heavy rain	No activity
		1st week-Dec	Moderate	No activity
		2nd week-Dec	Heavy rain	No activity
		3rd week-Dec	Moderate rain	No activity
		4th Week-Dec	Heavy	No activity
WARD	**Receiver Number**	**Week**	**Status of Rain**	**Activity to be done**
		1st week -Oct	moderate	No activity
		2nd week-Oct	Heavy rain	Start weeding
		3rd week-Oct	Heavy rain	No activity
		4th week -Oct	Heavy rain	No activity
		1st week-Nov	Light rain	Apply fertilizer
Kinampanda	+255744829002	2nd week-Nov	Light rain	Continue with fertilizers
		3rd and 4th week-Nov	Moderate rain	No activity
		1st week-Dec	Moderate rain	No activity
		2nd week-Dec	Moderate rain	No activity
		3rd week-Dec	cloud	No activity

	4th Week-Dec	cloud	No activity

Table 2 displays the application programming interface (API) test and validation results for the DSS's operations. Farmers with non-smartphones receive text messages after registering their mobile numbers and wards, as illustrated in Table 2.

Table 2

Validation results of SMS status for Non-Smartphone Farmers Using API

Date and Time	Direction of SMS	Sender Number	Receiver Number	Number of Segments	Status of SMS
2021-11-15 8:00:08 UTC	Outgoing API	(239) 237-3298	+255713285519	4	Delivered
2021-11-15 8:00:08 UTC	Outgoing API	(239) 237-3298	+255784727735	4	Delivered
2021-11-15 8:00:07 UTC	Outgoing API	(239) 237-3298	+255744829002	4	Delivered
2021-11-15 8:00:07 UTC	Outgoing API	(239) 237-3298	+255713285519	4	Delivered
2021-11-15 8:00:13 UTC	Outgoing API	(239) 237-3298	+255784727736	4	Delivered

Discussion

The needs of farmers in the Singida region, where access to agricultural information for well-informed decision-making was limited, served as the driving force for the development of the algorithm platform. Farmers in Tanzania were able to request meteorological information from the Tanzania Meteorological Agent (TMA) decision support system by using straightforward, reasonably priced smart phones and feature phones.

When it comes to pre-programmed set of activities and the weather or rain, farmers can utilize the API to communicate with the system and receive SMS notifications that are sent to them in plain language. In contrast to the findings of Masere and Worth (2021), who argued that the use of API improves the sharing of agricultural information among farmers, with a focus on technology that can be primarily used by farmers' computers and phones through web-based systems. The difference of these findings is that the current study has explored the remote locations where there is a challenge of internet connectivity to support the accessibility web-based system through laptops and smartphone. The bulk of farmers in rural areas also own feature phones. The study's conclusions showed that farmers who use feature phones or smartphones have advantages while utilizing DSA rural areas. Nhenio *et al.* (2019) and Tripath *et al.* (2022) have concurred with the study's findings, stating that most farmers own feature phones and are proficient in using the DSA.

Based on the findings of this study, a decision support algorithm was developed that allows farmers of all stripes to manage and access weather forecast data using feature phones and smart phones. The results of this study are corroborated by (Soyemi and Bolaji, 2018), who contend that it is extremely difficult to provide farmers with information solely through online applications because most farmers live in remote areas with poor internet connectivity. The results of this study support the effectiveness of this strategy in decision-making for higher productivity, requiring a web-based system as Nhenio *et al.* (2019) and Duca and Clapo (2021) claimed differently. This discrepancy can be attributed to the fact that earlier research of a similar nature was carried out in settings where technology was more developed than in the rural area where this study was conducted.

According to the findings of this study, the database as part of the DSA is crucial since it stores a predetermined set of faming activities as well as the classified state of the amount of rain. Similarly, the findings of Soyemi and Bolaji (2018); Churi *et al.* (2013); Tripath *et al.* (2022), the data base serves as the component that facilitates queries of stored information by making comparisons for decision making. According to previous research, it is adequate for DSA to use SMS-based mechanisms to convey information from weather sources by contextualizing it to farmers' everyday activities.

Differently to the findings of this study, TMA offered weather data throughout data collection; these data are frequently received over time and include daily, weekly, monthly, and annual weather forecasts; nonetheless, these data are inconvenient for farmers with feature phones while making farming decisions (Inovia and Bretiginieres, 2020). The findings of this study show that farmers need to be informed about weather conditions at every stage of sunflower growth, which sets it apart from previous research. Weekly meteorological data was used in this study; queries on the DSA are used to retrieve this data from the TMA and process it according to pre-defined parameters set on the system, giving the user clear and helpful information to help them make decisions. The findings of this study are comparable to those of Churi *et al.* (2013) and Ratna (2019) who proposed that farmers use satellite data to boost agricultural yield. Farmers must also be kept informed at all stages of crop development. Farmers require seasonal climate estimates prior to the start of the season in order to make strategic farm-level decisions that improve household food security and revenue.

This study discovered that TMA's credible meteorological information influences strategic farm-level decisions. Respondents used the information provided to select seeds, prepare land, and make crucial strategic decisions. Farmers' decisions to plant short-duration sunflower seeds were influenced by low rainfall estimates, according to this study. Irrigation proved to be the most effective means of adapting to unforeseen weather fluctuations. Inovia and Bretiginieres (2020) confirmed these findings by revealing that depending solely on weather data, including TMA, had no effect on sunflower yield. According to Inovia and Bretiginieres (2020), a decision support algorithm is required to convey processed information for decisions as well as to inform and compare weather information to farmers' normal operations.

The findings of this study suggest that the usage of AEOs is critical since they are specialists who can use the knowledge and aid farmers in making appropriate decisions. The TABD (2019) reports back up the study's findings by applying AEOs to aid farmers in reinforcing the usage of DSA information. The algorithm identifies the type of activity to be conducted at a certain ward by comparing the amount of rain observed and classified for a specific ward with the predefined daily activities, and then conveys information for use and subsequent action. The DSA mechanism is similar to that discovered by (Soyemi and Bolaji, 2018; Nhenio *et al.,* 2019; Churi *et al.,* 2013)

Sunflower growers in two separate wards assessed the DSA, and it was enhanced based on their usability comments, as proposed by Tripath *et al.* (2022) and Kaur *et al.* (2022). The findings of this study are similar to those of Zilihona *et al.* (2013) and Ireri (2020), who suggested that additional research is needed to assess the benefits of basic, low-cost mobile phones for smallholder farmers in rural areas.

In the DSA evaluation, the conclusions of this study demonstrate that the SMS is supplied over the API, and the status is clearly displayed in Table 2. According to the research, farmers who are not as tech-savvy can also receive SMS messages that tell them of what needs to be done about various farming activities in light of the current rain situation. The SMS engine interface of the DSA was utilized to monitor and analyse communications amongst famers utilizing feature phones. Participants provided positive comments and requested more information when asked if they had received SMS messages in response to the DSA requests they had made throughout the evaluation. The results of this study were corroborated by Masele and Worth (2021), who proposed that technology support users of both smart phones and feature phones be implemented. They continue by saying that most farmers in rural areas utilized feature phones, which makes sense since there is no internet connectivity.

The findings of this study used API queries for reading weather data from TMA as input to DSS, which is the monthly or weakly rain amount or quantity. Pre-defined database-stored criteria are used to classify this raw data. Furthermore, the weather data stored in the database was compared to the seasonal sunflower activities carried out by sunflower farmers in Singida, which were also pre-defined and stored in the database. DSS compares the amount of rain recorded for a specific ward to the programmed classified amount of rain as a criterion and translate it and intended information in relation to the set of activity. The findings of this study further make decision by disseminating translated information to farmers for action informs of SMS. The findings of this study differ from the findings of other previous studies which neglected the incorporation of SMS-engine that disseminate information to famers with feature phones (Inovia and Bretiginieres, 2020; Nhenio *et al.* 2019; Masere and Worth, 2021)

Conclusion

The use of ICTs to simplify decision-making among sunflower farms in a sequence of operations under changeable weather circumstances has the potential to have a significant impact on farmers' efforts to increase yields. According to the findings of this study, farmers in Tanzania can make informed judgments regarding a variety of agricultural activities by leveraging feature and smartphone phones to get weather forecast information from TMA through the use of DSA developed.

Even though sunflower products in the Singida region significantly contribute to household income, small-scale farmers are facing low crop yields, attributable to ineffective decision-making processes. The current decision-making tools, such as algorithms, rely on farmers having smartphones and internet connection, yet the majority of farmers possess feature phones and lack internet access. Additionally, current systems do not include all crucial decision-making components in a way that allows them to deliver information about options independent of actual agricultural activity. Currently, farmers use local indicators to predict the forthcoming season's features and organize farm management. In contrast to new technologies, farmers assume those traditional knowledge systems, which have developed through generations, are safer, and less risky. However, since these systems were not designed for this purpose, continual dependence on them renders it difficult for farmers to adapt to weather variations

This study is significant in general because, through the developed and validated decision support algorithms (DSA), both farmers with smart and feature phones benefits not only from the context of Tanzanian rural areas, but also from other rural areas in developing countries, including Africa, that have been affected by weather changes. This is because the DSA assists farmers with feature phones and smartphones in making decisions depending on their set of farming activities, independent of the availability of internet connectivity in remote locations. Farmers considerably employ the informed decision information from DSA to boost productivity of sunflower and other crops farmed in areas with similar characteristics to the Singida region of Tanzania.

This study recommends that improving the amount and quality of sunflower production under changing weather circumstances is one thing, but when and where to sell the products remains a difficulty, most likely necessitating suitable and integrated technology to give marketing information for optimal outcomes. Future studies should think about including marketing information and weather changes into the DSA to boost production and selling as critical components of the farming supply chain. Furthermore, agricultural DSA development should focus on connecting research inputs and making research findings available to farmers and other agricultural operators.

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