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A Framework of an Online Crop Prediction Model using Python Software

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Abstract

The agriculture sector is struggling to increase the productivity of crops in developing and underdeveloped countries. Due to variations in crop yield determining factors such as climatic conditions, there are bottlenecks for aggregate crop production. In addition, the region or area-specific major influencing factors directly impact the production and productivity of the crops. Consequently, farmers also need relevant information regarding crop yield before sowing seeds in their fields. But typically, farmers are unaware of the challenges and opportunities in crop production. There is a need to generate relevant information to enhance crop productivity and crop yield prediction has become one of the critical factors in agriculture practices. Besides, to achieve high crop yield, information at the farmers end should be available instantaneously. This paper proposes a framework for an online crop prediction model using Python, a web-based platform so that farmers can get access to real-time information. This study initially identifies the requirement of the crop yield prediction model with the assessment of agriculture experts in Meghalaya and then establishes the relationship with structural equation modeling. Finally, the model is validated with test data. The study contributes in anticipating the crop yield under given conditions and disseminates relevant information to support farmers for optimum crop production. As a result, farmer may know how much yield is expected with their accessible resources. Further, the result of the study would be helpful to the policymakers and stakeholders towards sustainable agriculture development.

***Key words*:** Online, Crop prediction Model, Farmers, Agriculture, Python

In many developing countries, with a rapidly growing population, agriculture plays a vital role in the economy and stable income generation [1]. In these countries, agriculture is the backbone of the economic system and is the core basis for livelihood and poverty alleviation. It also provides employment opportunities to a substantial percentage of the population and has a vital role in sustainable development and GDP contribution. Thus, the development of the agricultural sector in these countries, including India, has been crucial [2]. Statistics reveal that India lies in fourth position in the list of leading agricultural countries across the globe. Besides, it is considered that around 85.4% of the Indian population is associated with the agriculture sector for their livelihood.

The northeastern region of India, being a reservoir and potential of valuable natural resources, is struggling in the agricultural sector. The sector is cropped up with multiple problems of decline in agricultural products such as soil problems, land and water degradation, low potential areas of eastern India, and marketing and finance issues. The region failed to nourish its resources mainly due to a lack of awareness, information, and knowledge. There is an urgent need to generate relevant area-specific information and knowledge for high yield through a suitable crop yield prediction model, a critical factor in agriculture practices. In this backdrop, this paper attempts to design a framework for online crop prediction model.

The paper is organized as follows: initially, in section one this introduction and then section two briefly highlights background of the study. Section three is devoted in discussing methods and section in designing the model. Finally, section five argues the empirical findings with discussion.

Background of the study

This section initially highlights various challenges to Crop Productivity and the need of online crop yield prediction model. Then reviews various literature related to web-based technology and design of online application.

Challenges to crop productivity

In developing countries, crop productivity being a critical indicator of agricultural growth, poses a significant risk due to yield-reducing factors. To reduce yield losses, these factors must be properly identified, monitored, and managed [3]. In India, agricultural crop productivity is determined by many factors, and the factors that affect agricultural crop yield in India are mainly geographical or physical (such as land topography, land preparation, land suitability, traditional cropping system, seed treatment, variety of seeds, method of irrigation, harvesting, weeding, channel features such as soil texture, structure, soil depth, and topography), atmospheric parameters (such as climate, temperature, radiation, relative humidity, wind velocity), economic factors (market facility,

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transport facilities, labor, capital, government policies), technological factor (irrigation, fertilizers, farm machinery, crop pest, agricultural practices, managerial decision, etc.) [4-7].

The other factors that influence crop yield are biological elements (diseases, insects, pests, weeds), suitable crop varieties, input (seeds, planting, materials, fertilizer), Integrated farming system, soil and water conservation, irrigation/drip irrigation, post-harvest technique, farm machinery/implement, market information, farm credit/subsidy schemes, Government schemes on agriculture, horticulture, announcements related to the farmers' training program and Crop insurance [8].

In summing up, agricultural production and high crop yield are restricted by several challenges and these factors can be altered by a limited intervention that may subsequently enhance crop productivity.

Requirement of online crop yield prediction model

Crop yield depends on a variety of factors and these factors are likely uncertain. Consequently, in agriculture, actual time and historically generated data are generated by on-site farming, satellite farming, etc. in an unstructured and structured data format called precision agriculture [9]. Research affinity is currently to find out the knowledgeable information of the data gathered from the different sources of precision agriculture for predictive decisions [10-11]. The agricultural sector requires enhancement in the process of decision-making that can be used to increase the quantity of data and information, that comes from a broader number of different resources [12].

Few researchers [13] claimed that, in these uncertainties, yield prediction that considers all major yield-determining factors can help the farmers predict future crop yield [14]. Crop prediction models aim to provide a solution for predicting yield production with high precision and generalization. Few previous studies [15] added that using one single model is preferable to predict crop yield than using an ensemble of numerous models. However, there is also little information regarding the crop prediction model that takes into account all the major determinants of crop yield within the targeted agro-ecological zones.

In addition, developing as well as underdeveloped countries are still lacking in using technology as well as supporting the farmers with real-time information in the field. According to few researchers [16] technological backdrop may be overcome through a few web-based technologies and however they also concluded there is a general perception that the implementation of web-based is complex and costly. Web services and web-based technologies are used to build up web portals or web pages that provide centralized facilities for searching, extracting, accessing, interpreting, and processing information [17]. Web portals are defined as the entry points for exchanging information over the internet and technological limitations are naturally overcome by the portals, thus increasing the communication and information-sharing process. The web portal has the potential to provide a common system where data can be stored from different data sources, organizes them, and provides with consistent look and feel to the users.

In a nutshell, the above discussions suggest that an online crop prediction model concerning to North-Eastern region of India would greatly support farmers in responding to uncertainties related to field-level activities. Thus, the present study primarily focuses on designing a framework for an online crop prediction model, particularly for farmers of the north-eastern region of India in General and the state of Meghalaya in particular. During the field study, it was noticed that in Meghalaya, rice and maize are the primary food crops, and the major fruits grown are orange, pineapple, lemon, guava, jack fruit, and bananas. The main commercial crops are cashew nut, potato, jute, cotton, areca nut, ginger, turmeric, betel leaf, and black pepper [18]. But farmers are making decisions on farm activity without much knowledge and information regarding these crops. Consequently, they are facing difficulties in managing yield-reducing factors and eventually yield loss.

Advantages of web portal and web-based framework

A few studies [19-20] stated that any online application or Web Portals provide a useful medium to access data and share information and knowledge people which in turn helps to improve productivity, and management function, limiting the redundancy and time. These Portals are the means to empower individuals and are not constrained by barriers such as physical and demographic. Few authors [21] mentioned that organization access different sources of information by integrating and developing web technology frameworks such as web portals into their business operations which act as a single window website across the internet. With a web portal framework, firms can reach out to consumers irrespective of boundaries and provide them with information about various products or services along with the opportunity for interactive transactions of business.

Several authors [22] defined a Web portal as an online application that helps to take information from diverse data sources and presents them in a unified way to offer another service. They developed a structural framework for a website and indicated a web portal as a medium for integrated marketing. These portals are entrance points for information management and trade over the internet and act as an important tool to share ideas, and knowledge acquisition, publish documents, and save information used by a society of interest [23-24]. They viewed web Portals as are efficient way to create and manage information via the internet and help to transfer knowledge through various modes of communication channels and to reach further than the one-sided information exchange available in traditional websites.

Maedche *et al*. [25] observed that a Web Portal (known as a links page) helps to present information from different sources in an integrated way and is considered a dynamic rather than a static web page i.e. website. It makes network resources (applications, databases, etc.) available to end users via a web browser and other devices and provides network-enabling services such as e-mail, chat rooms, and calendars that interact seamlessly with other applications.

Sudharshan [26] showed that three separate units should be considered for all Web portals and Web users. These are advertising space, overall appearance, and how it communicates and all of these can be analyzed through a Web page. This can be visible through the number of visits to the page and based on the amount of time spent on a particular page. A Web portal can be analyzed to determine how the overall structure of the site influences the corporate communication and marketing strategy. The Web users can be analyzed, so that the reasons for their particular behavior and usage of certain products/services can be discovered.

Design of web portal or online application

Balaraman and Kosalram [27] observed that business models of today are highly dependent upon internet-based transactions, online platforms, and the use of web portals. To cover a maximum segment of their consumer, many small firms have started realizing this need particularly quality web portal frameworks but very few organizations have the idea and knowledge of building quality web portal frameworks. Krause

[28] stated that there exists no structured web framework or any process that would help to build quality websites. However, in the literature, various ways were highlighted to design quality web portals and organizations should focus on building quality web portal frameworks according to individual requirements. Few studies [29-30] indicated that basic IT skills and a foundation of software are required while designing and developing web portals. It is necessary to know the audience requirement, the nature of the data, and the database where data is to be stored. Finally, an eye-catching website should be designed with features such as design, high speed, completeness, responsiveness, and the ability to be updated according to the needs of a user to make it special from other existing portals. Wen *et al*. [31] explored the website design strategies and models for E-Commerce and identified the variables such as customer service and relationship, information consistency, cost saving, better customer service, product promotion, timely information, customization of products, competitive advantage and explained some of the website design models such as brand awareness model, cost-saving model, etc. The fundamental factors for designing and development purposes are brand, navigation, fulfillment, presentation, up-to-date technology, and seals of approval other important features found to create a website for customers are customer service (contact number available, clearly state return policy, the possibility of returning a purchase at the nearby store), testimonial and security feature representation such as text and graphic. Pulumbarit *et al*. [32] have developed a web-based application using different front-end software such as PHP, Visual Basic, .Net, and RDBMS and these applications captured the user and system requirements. Furthermore, the application was evaluated based on criteria such as maintainability, functionality, usability, reliability, and security. It was tested for its performance and security by technical people while the users evaluated the acceptability of the system. Moertini *et al*. [33] viewed that E-Marketing Web Portal should be developed to support small and medium enterprises. The proper design, development, and implementation of web-based technologies embedded with marketing strategies will help the firm market its product and conduct its business effectively. However, none of the theories, models, and empirical studies could highlight the design aspect of the online application for crop prediction model in India in general and North East India in particular.

MATERIALS AND METHODS

This study was conducted in Meghalaya, considering the representative of the hilly areas of Northeastern regions of India. This region is selected considering that the region has the highest growing units in terms of employment generation, productivity, and net income and it occupies a significant place in India's plan for economic development both for socio-economic as well as geo-political reasons. But at the same time, it is observed that the NER of India has often been visualized as the remote landlocked backward region of a dynamic economy the relatively low development indicators, lack of adequate information about new or advanced technology, high poverty rates, region impacts on the country's overall progress.

To arrive at the sample, an equal number of 6 (six) agricultural experts as respondents are considered from each of the twelve districts of Meghalaya state through convenience sampling. A questionnaire was distributed to these respondents, and subsequently, data was availed from the respondents. The questionnaires are presented on a five-point Likert scale (5 for highly satisfied, 4 for satisfied, 3 for neither satisfied nor dissatisfied, 2 for dissatisfied, and 1 for highly dissatisfied). A total of 72 no. of questionnaires were distributed to the sample respondents of agricultural experts. Out of which 60 nos. responses, finally considered for the study. To design the proposed framework. The waterfall model, also known as a five-stage design life cycle is used. However, for the study only first three phases of the waterfall model are considered. In order to build the model, Python, an interpreted, object-oriented, high-level programming language on web-based platform is used. Initially, model building process started with gathering requirements and establishing relationship with Structural Equation modeling. Then in order to build and validate the model, collected responses were partitioned into two groups. 80% of the responses i.e. 48 no responses were used for building the model and the rest 20% was used for testing the framework.

Design of the online crop prediction model

The crop prediction model with this proposed system was developed with the responses received from the sample respondents. In order to design a framework for the Online crop prediction model, the first three phases of the waterfall model are considered. The last two phases which consists of deployment and maintenance are out of the scope of the study. The three phases are namely requirement gathering and identification, analysis, and design phase. These phases are discussed below:

The user requirements analysis is the process of understanding and determining features required for the system. To build the model the questionnaire was designed based on an initial set of variables that were chosen based on their relevance and contribution to the agricultural field as shown in (Table 1). The questionnaires are presented on five-point Likert scale (5 for highly satisfied, 4 for satisfied, 3 for neither satisfied nor dissatisfied, 2 for dissatisfied, and 1 for highly dissatisfied. Then expert opinions were recorded for the study area to identify the key factors that are responsible for crop yield.

In the analysis phase, all the information and requirements for the model are gathered for analysis. The primary role of this part is to eradicate incompleteness and inconsistencies related to the software product or model to be developed.

Table 1 List of constructs affecting crop yield

S. No.	Category of variables	Construct	Categorical variables
1.	Predictors	Crop-agricultural production	Land area usage, land situations, method of sowing, land preparation, harvesting, varieties, traditional cropping system, seed treatment, method of irrigation, harvesting, varieties, weeding frequency, manure frequency, fertilizer frequency, Weather, and time of sowing [4], [34-36].
2.		Crop-soil suitability	Quality of soil, soil texture, soil structure, soil density, soil temperature, soil fertility, soil color, soil composition, soil depth, soil stickiness, soil plasticity, moist soil, dry soil, soil pH, major nutrient, minor nutrient, fertilizer usage, manure usage [37-39].

3.		Crop-irrigation and water facilities	Quality of water, type of irrigation size, irrigation canal, irrigation management, irrigation purpose, irrigation sources of water, irrigation conveyance system, surface irrigation system, surface drainage system, drainage ownership, drainage duration [40-41].
4.		Crop-pest control	Pest control (PC) natural, PC applied conventional, PC applied modern, PC integrated pest management, protection on chemicals [42-44].
5		Crop-agricultural economics information	Nature of agricultural production, agricultural finance, market seller, market time, market competition, market regulation, market area, market function, the market volume of sale, fluctuation in agricultural price, and farmer's attitude [45-46].
6.		Crop-sustainability strategy	Types of traditional farming, a system of farming, types of cooperative farming, agricultural labor, elements of sustainability, conservative farming, agricultural sustainability [47]
7.		Crop-agricultural constraints	Land problems, irrigation problems, indiscriminate use of agrochemicals, vulnerability problems, Environmental problems [37-38], [40], [46].
8.	Response	Crop-yield	High (H), Low (L), Neutral (N), Very high (VH) and Very low (VL).

Table 2 List of Constructs used crop prediction model using for SEM analysis

S. No.	Construct	Item	Code
1.	Agricultural production (AP)	Method of sowing	MOS
		Time of sowing	TOS
		Land preparation	LP
		Land situation	LS
		Traditional cropping system	TCS
		Seed treatment	ST
		Method of irrigation	MOE
		Harvesting	HAR
		Varieties	VAR
		Local weather parameters	LOCWEA
		Weeding frequency	WEDFREQ
		Manure / fertilizer frequency	MAFE
2.	Weed specification (WED)	Life cycle	WEDLC
		Seed types	WEDST
		Habitat	WEDHA
		Origin	WEDOR
		Relative position	WEDRP
		Crop weed relationship	WEDCR
		Method of weed control	WEDCONT
3.	Diseases (D)	Types	DT
		Causes	DC
		Symptoms	DSYM
		Protection on chemicals	DCHEM
4.	Soil consistency (SC)	Wet soil stickiness	SSTICK
		Moist soil	SMOIST
		Dry soil	SDRY
5.	Soil suitability (SS)	Quality of soil	QOS
		Soil texture	STEX
		Soil density	SD
		Soil temperature	STEMP
		Soil fertility	SF
		Soil colour	SC
		Soil composition	SCOM
		Soil depth	SDEP
		Soil strategies	SSTRAT
		Soil pH	SPh
6.	Soil fertility (SF)	Major nutrient	MAJNUT
		Secondary nutrient	SECNUT
		Minor nutrient	MINNUT
7.	Pest control (PC)	Pest control natural	NAT
		Pest control applied conventional	ACON
		Pest control applied modern integrated pest management	AMODIPM
		Protection on chemicals	POC
8.	Agricultural economic information (AEI)	Nature of agricultural production	NAP
		Agricultural finance	AF
		Market classification seller	MCS

		Market classification time	MCT
		Market classification competition	MCC
		Market classification regulation	MCR
		Market classification area	MCA
		Market classification function	MCF
		Market classification volume of sale	MCVOS
		Fluctuations in agricultural prices	FAP
		Types of traditional farming	TFAR
		System of farming	SOF
		Types of cooperative farming	TOCF
		Agricultural labour	AL
		Elements of sustainability	EOS
		Conservative farming	CF
9.	Manure / Fertilizer usage (MAFTUSA)	Manure / fertilizer usage	MAFTUSA
10.	Sources of water (SOW)	Quality of water	QOW
		Water availability	WAVA
		Uses of water	UOW
		Types of irrigation size	TOIS
		Types of irrigation class/canal	TOIC
		Types of irrigation management	TOIM
		Types of irrigation purpose	TOIP
		Types of irrigation sources of water	TOISOW
		Types of irrigation conveyance system	TOICS
		Surface irrigation system	SIS
		Surface drainage system	SDS
		Drainage system ownership	DSO
		Drainage system duration	DSD
		Drainage system origin	DSDO
		Quality of water	QOW
		Water availability	WAVA
		Uses of water	UOW
		Types of irrigation size	TOIS
		Types of irrigation class/canal	TOIC
		Types of irrigation management	TOIM
		Types of irrigation purpose	TOIP
		Types of irrigation sources of water	TOISOW
		Types of irrigation conveyance system	TOICS
		Surface irrigation system	SIS
		Surface drainage system	SDS
		Drainage system ownership	DSO
		Drainage system duration	DSD
11.	Problems of agriculture (POA)	Land / soil problems	LSP
		Irrigation problems	IP
		Indiscriminate use of agro chemicals	IUAC
		Vulnerability problems	VP
		Environmental pollution	EP
12.	Level of crop yield (CY)		
	Exogenous variables	S. No. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	
	Endogenous variables	S. No. 12	

The collected data are recorded in CSV file against the items coded as shown in (Table 2). The reliability of collected data is tested with internal consistency, Cronbach alpha and the overall value found is above cut-off limits, that is 0.7. Then to conduct structural models, the collected dataset must satisfy two assumptions and these are a) a larger sample size and b) multivariate normality. This study involves a relatively large sample (48 numbers are sufficient as it is more than 40 no which is enough for a multivariate analysis) and therefore, the Central Limit Theorem could be applied. Hence there is no question about the normality of the data. Finally, SEM analysis was conducted with the SEMOPY package in Python to establish the relationship between exogenous and endogenous variables as mentioned in (Table 2).

Finally, developed pages are tested. Testing is the essential phase which considers all the improvements and defects that need to be corrected and analyzed. Finally, it was done to check whether the proposed model was functioning properly and whether all the user requirements had been covered or not. The web portal was deployed on the local server which might be deployed over the internet in future research. The web portal needs continuous and constant monitoring to measure the performance of the web portal. Then predict method of the Semopy model is used for predicting the crop yield. The model is validated and tested with 20 % test data identified earlier. Finally, after comparing the model responses with the actual responses, errors for the crop model are obtained. The model obtained 81 percent accuracy and hence the model may be considered for the crop prediction.

Furthermore, farmers will need to sign up for the system by filling up an online dialogue which will contain their details. Once the form is filled, the same must be submitted, and their

information will be loaded into the in-built database of the model. Once the form is submitted successfully, an ID and password will be sent to their respective email ID, which is provided during the sign-up stage. Then the farmers will have to sign in by providing the generated ID and password to use the system. Finally, the model then can be deployed on a web server so that farmers can access the same to get relevant information on the field.

RESULTS AND DISCUSSION

In India, crop yield is season-dependent and majorly influenced by a particular crop's economic and biological factors. To achieve sustainable amplification of agricultural yields, it is necessary that the farmers are aware and informed about the yield gaps. The paper attempts to design a framework for an online crop prediction model with a small dataset. The result from the present study shows that the model successfully predicted the test data with a reasonable error limit. The model is just an attempt to build an online crop prediction model. The study initially identified the requirement of the crop yield prediction model and then based on the waterfall model, an online crop prediction model has been designed and validated.

The proposed model brings farmers to a platform that provides a friendly system for increasing productivity and saving time and cost. This model can be available on the web with vibrant features to open a new horizon. This research represented a starting point for farmers to adopt online web-based knowledge systems that are greatly needed to overcome geographical limitations. A web portal framework serves as a guide for farmers in the long term and has the potential to transfer valuable information and provide innovative activities. The developed model for crop yield would help decision-makers and policymakers conceptualize and visualize the growth of farmers. In addition, this key factor of the model can be combined with new theories and models for further studies in the future. The same strategy can be applied to various other crops and eventually, corrective measures can be undertaken to increase the yield of the crop.

Finally, in North Eastern Region (NER), India farmers are more stressed in producing higher crop yields due to the influence of unpredictable environmental changes and significant reduction of water resources), and therefore predicting the crop yield well in advance before its harvest can help the farmers and government organizations to make appropriate planning like selling, storing, fixing minimum support price, importing/exporting, The yield prediction model may provide a unique opportunity to overcome challenges and improve crop yield gap prediction ideology. The proposed system is just a framework that has some limitations which can also be considered as a future enhancement; In the absence of real and online data, the developed system predicted crop yield only by a primary survey of the experts. The policymakers and stakeholders should be focused on creating a database with real and online data and the government should initiate implementing agricultural technology to store such data in real time. Finally, the opportunities provided by web-based technology data should be adopted by the farmers to expand their crop production effectively and remain competitive in the market.

CONCLUSION

In conclusion, the study successfully designed and validated an online crop prediction model tailored for India's season-dependent crop yields, significantly influenced by economic and biological factors. This model aims to enhance farmers' awareness of yield gaps and promote sustainable agricultural practices. The results demonstrated the model's ability to predict test data with reasonable accuracy, indicating its potential as a valuable tool for farmers. The proposed web-based model offers a user-friendly platform for increasing productivity while saving time and costs. It represents a significant step towards adopting online knowledge systems to overcome geographical limitations and provide long-term guidance to farmers. By integrating innovative activities and valuable information, the model aids decision-makers and policymakers in conceptualizing and visualizing agricultural growth. Despite its promising potential, the model has limitations, primarily due to the lack of real-time data. Future enhancements should focus on creating comprehensive databases with real and online data, supported by government initiatives to implement agricultural technology. By embracing these opportunities, farmers can effectively expand their crop production and remain competitive in the market. The model's framework also opens avenues for further studies, applying the same strategy to various crops and addressing the challenges posed by unpredictable environmental changes and resource constraints. Ultimately, this crop yield prediction model offers a unique opportunity to advance agricultural practices and improve crop yield gap prediction.

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