Machine Learning Based Intercropping Recommender

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***Abstract*— Intercropping is the agricultural technique for growing two or more crops in the same area simultaneously. It is a popular cropping method that tries to effectively match crop demands with the people and growth resources that are available. Using crops with different rooting abilities, canopy structures, heights, and nutrient needs to increase production on a specific piece of ground by more effectively utilizing the available growing resources. The crops are combined based on how effectively they each use growth resources to achieve this. Intercrops can boost pasture's output of crude protein, which lowers bug occurrence and raises the quality of fodder production. In places susceptible to inclement weather like fog, drought, and flooding, intercropping provides protection against crop failure and shifting market values for a specific item. It is therefore better for financial security than lone cropping and is perfect for small farms that require a lot of effort.**

Keywords—Intercropping, Nutrient, Agriculture, Yield, Pasture, Crude

I. INTRODUCTION

Agricultural method of Intercropping, sometimes referred to as polyculture or mixed cropping in which two or more crops are grown side by side on the same field [14]. Although they don't have to be planted or harvested at the same time, the component crops of the intercropping system should be cultivated together for the majority of their growth phases.

Although they can also be distinct cultivars or types of the same crop, such as cultivating two or more varieties of wheat in the same location, intercropping typically involves two or more crops from different species and plant groups.

The main benefit of intercropping is that it increases yield by more efficiently utilizing the growth resources that would otherwise be squandered if each crop were grown independently on a given area of land [15]. You can interplant both annual and perennial plants. Since interspecies interactions, readily available management approaches, and environmental conditions all have a large effect in the success of intercropping systems, choosing the appropriate intercropping system for particular situation can be fairly difficult. By examining and harnessing genetic variation for intercrop adaptability, plant breeding can considerably increase the productivity of intercropping systems.

In India, 60% of the total area used for agriculture is retained as a rainfed environment, where crop production is dependent on rainfall and where irrigation is neither lifesaving nor protective[16]. In reality, India is the world's largest rain-fed agricultural country in terms of both output value and land area. The food consumed by 40% of the people in the country comes from farmland that is rainfed. These areas experience 400 to 1000 millimetres of inconsistent, chaotic, and ill-distributed yearly rainfall.

As a result, food production typically experiences a sharp fall. Rainfed agriculture is therefore most affected by climate change. Changes in wind, temperature, and rainfall patterns are now more frequent in rainfed ecosystems as a result of climate change[19]. Additionally, due to the declining number of rainy days and rising intensity of rainfall, both of which result in major crop losses, immediate action is needed to restore the stability of rainfed ecosystems. Intercropping is a crucial tactic in the context of climate change for preventing crop failure in rainfed agriculture while simultaneously boosting productivity and profitability by maximizing the use of natural resources. ANNs[18] were used to create a model for predicting rice crop yield. Intercropping reduces the likelihood of disease and pest infestation, enhances the utilization of moisture and radiation, enhances weed management, guards against drought, and, overall, raises and stabilizes productivity. Intercropping has been found to function as a type of biological insurance against the dangers that erratic rainfall patterns pose. Variety in crops is essential to preserve the health of the soil, increase yield and return, and gain other advantages the applicable criteria that follow.

II. TYPES OF INTERCROPPING SYSTEM

Intercropping systems can be categorized into the following groups:

A. Row Intercropping

Fig. 1. Row intercropping

Row intercropping is the process of growing intercrops in or out of rows while one or more crops are grown in regular rows, as depicted in Fig. 1.

B. *Mixed Intercropping:*

A variety of intercropping techniques in mixed intercropping, many crops are grown side by side without regard to the ratio of one crop to another [17]. Occasionally, it is also referred to as "mixed cropping," as seen in Fig. 2.

Fig.2. Mixed intercropping

A good example of mixed intercropping is grass-legume intercropping in a pasture-based cropping system. When land resources are limited, mixed intercropping is widely used to meet food and forage needs. Furthermore, a review paper identified as an agro ecological method in cropping systems, perennial polycultures with sufficient long-term potential for spatial and temporal intensification of agricultural systems.

C. *Strip-Intercropping:*

Strip intercropping, as depicted in fig. 3, is a type of intercropping where two or more crops are cultivated in strips on muddy ground. It is known to increase the utilization of radiation in underdeveloped and marginalized places.

A mixture of soil-conserving and soil-depleting crops are planted in alternate strips parallel to the slope of the ground or the direction of the prevailing winds. Strip cropping's primary objectives are to decrease soil erosion and collect agricultural yield from underdeveloped sites.

Fig.3. Strip intercropping

D. *Relay-Intercropping:*

Relay intercropping is the practice of growing two or more crops simultaneously during a portion of each crop's growth season. In this procedure, the second crop is sown when the first crop has substantially finished its life cycle, has arrived at the reproductive stage, or is almost at maturity but before harvest.

Fig. 4. Relay Intercropping

Relay cropping is better suited to regions where time and soil moisture are limited. According to fig. 4, the following crop is planted before the one before it is harvested, and both crops stay in the field for a portion of their life cycles. Sequential cropping yields less than standard sowing, though, and more seeds of the future crop are required to establish a strong stand.

III. Literature Survey

[1] The recommended method enables crop production forecasting based on historical data that considers elements including crop name, temperature, humidity, and pH. In all of India's districts, this method will cover the broadest range of crops. With the aid of decision tree and random forest algorithms, we may use the suggested technique to anticipate the best crops based on the local weather. Crops are predictable. The random forest method was used to get the most precise result. The profit from the agricultural production grew with more precise results.

[2] They have outlined a crop selection method in their work (CSM) is a strategy for increasing agricultural yields seasonally through net yield rates. Every year, the summer rainfall depth in India determines the entire season of the year. Based on expected season and it is possible to estimate crop yield rate sooner using historical crop yield rate data. The CSM algorithm predicts crop yield rates based on favourable conditions ahead of time and generates a list of crops with the highest yield rate.

[3] Focuses on Crop planning's major goal is to increase profit and production while reducing input costs and resources. The idea of crop planning and many techniques used to do so, as well as problems that call for practical improvements. Crop rotation and intercropping are two examples of improved crop planning patterns that can be used to implement beneficial agricultural practices. It can be solved efficiently using computer approaches, resulting in the most ideal solution.

The Cuckoo Search, Genetic Algorithm, Particle Swarm Optimization, Glow worm Swarm Optimization, Firefly Algorithm, and Differential Evolutionary Algorithm are just a few examples of the bio-inspired algorithms that researchers use to solve crop planning challenges.

[4] This study describes how ANNs were used to create a model for predicting rice crop yield. The back propagation strategy and the adaptable artificial neural network technology are used to make the prediction (ANNs). This methodology has been demonstrated through the forecasting of rice crop yields for the Kharif season in Maharashtra, India, from 1998 to 2002.

The yield and a number of predictor variables, including precipitation, minimum temperature, average temperature, maximum temperature, and reference crop evapotranspiration, were used. In the present study, multilayer perceptron's were used in artificial neural networks.

[5] Purposed of a crop monitoring has become easier and more efficient because to the Internet of Things, which has increased agricultural yield and, as a result, farmer profitability. Data on crop status and environmental changes are gathered using wireless sensor networks and a variety of sensors, which are subsequently transmitted through the network to the farmer or other equipment that takes corrective action.

Farmers are always linked and aware of the state of the agricultural industry, no matter where they are in the world. Some communication difficulties must be solved by improving technology to consume less energy and by making the user interface simple to use.

[6] In order to establish long-term smart agriculture, it is required to better understand various technologies for IoT sensor monitoring network technologies, which use cloud computing as their foundation. A wireless network is used to address the fundamental IoT agriculture model, and it is concluded that an ideal Agri-IoT architecture must be created that offers optimal performance, superior decision-making processes, QoS services, cheap costs, and reduced device power consumption. It is also simple enough for a farmer to understand without technical knowledge.

[7] Focuses on the challenge of supporting and building specialized agricultural operations using Unmanned Aerial System (UAS) platforms and Remote Sensing (RS) technology, such as maps and sensor-based Variable Rate Applications (VRA). The conclusion is that, even if limited to drone-driven images, a worldwide and reliable quantitative analysis is currently unachievable.

Until far, grey literature has served as the primary source of information regarding real manufacturing solutions. Future franchises for closed solutions from large ICT businesses or open collaborative platforms for state collective farms could be provided for big data and complicated image processing for smart farms.

[8] A system that uses sensors, Arduino board to track the movement of animals that can destroy crops in an agroecosystem, including temperature, humidity, and moisture area can alert the farmer by SMS and an app created for the purpose if there is any deviation from the norm. The technology also detects animal invasions, which is one of the leading causes of crop loss.

This system creates irrigation schedules based on real-time field data and data from the meteorological repository. This technology can tell farmers whether or not they need to water their crops. It is necessary to have constant internet access.

[9] This paper presents a highlights of Internet of Things ecosystem, as well as highlighting future trends and opportunities, which are broken down into technological innovations, application scenarios, business, and marketability, smart agriculture is also discussed as a result of the integration of IoT and DA. IoT and data analytics advantages are then noted and discussed. The agricultural sector is projected to profit from the Internet of Things in a number of ways.

[10] This system interested in using the R language to find diseases that affect paddy. We get better outcomes by upgrading the training images. Images of damaged leaves are used to discover illnesses in rice utilizing R programming and convolutional neural networks. Three distinct diseases—Bacterial Leaf Blight, Brown Spot, and Leaf Smut—are represented by the photos of illnesses, which come from the UCI Machine Learning Repository.

[11] In LCC-based classification, the proposed method automates the human collection and evaluation of leaf color. A total of 6000 Aman paddy leaf photos are used in the experiment. The data was collected using our built application, which followed IRRI's instructions for obtaining paddy leaf photos within the body shade. The primary goal of this project is to create a mechanism for automatically categorising paddy leaves based on their digital photographs. Images of paddy leaves are used as inputs first.

[12] Author proposed method describes the classification of rice leaf disease; various methodologies are used. Otsu's approach is used to segment images of leaf diseases caused by bacteria, including brown spot and leaf smut. It separates different features from the segmented region using "Local Binary Patterns (LBP)" and "Histogram of Oriented Gradients (HOG)".

Diagnoses diseases that injure rice plant leaves, allowing farmers to quickly rescue their harvests. Various additional ailments can be found in the leaves of different plants, including rice leaves, can be detected using SVM+HOG using a polynomial kernel function. If plant illnesses are diagnosed early enough, farmers will be able to save their crops.

[13] The mathematical programming paradigm for an ACP that allocates space for expanding is suggested in this research. wetland and drylandcrops for the purpose of maximizing overall profit, while utilizing the least amount of water for irrigation of various crops. By figuring out how to update solutions using Simplified swarm optimization (SSO), which enhances PSO, is known as PSO.

It offers a dynamic SSO where the probability is dynamically modified to resolve the above-mentioned ACP in accordance with the outcomes of the operations carried out. This work is beneficial to agricultural government agencies and enterprises in practise. They may efficiently provide crop production in sensitive land places prevents land subsidence and produces valuable ACP using the needed parameters of the suggested model.

IV. PROPOSED METHODOLOGY

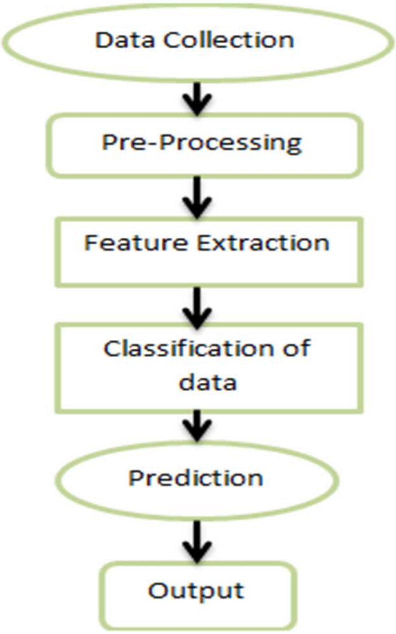


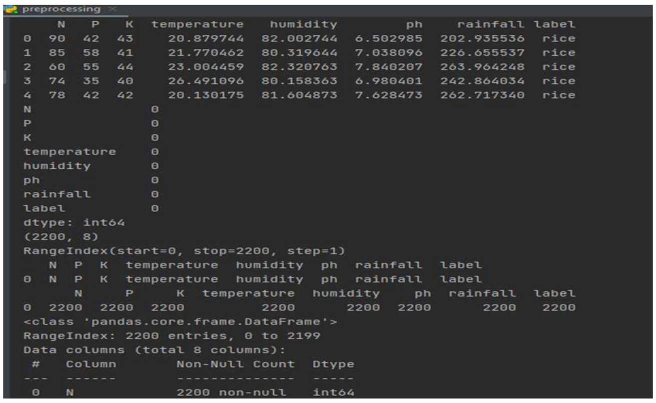
Fig. 5. Proposed System Architecture of Intercropping Recommendation System using Machine Learning

The suggested system will determine which crop is best suited based on intercropping techniques like row intercropping, mixed intercropping, strip intercropping, and relay intercropping, which are specifically based on soil type and weather parameters like temperature, humidity, soil pH, and rainfall, NPK, yield (kg/hectare), and cost (per hectare).

According to Fig. 5, the suggested system's architecture is as follows:

4.1. Data Collection: To gather and analyses data from various sources, including data collection, Kaggle and the UCI machine learning repository are being used to gather a fundamental dataset for the system [15], which might include elements like: I soil pH (ii) soil type (iii) temperature (iv) humidity (v) rainfall (v) NPK levels and so forth.

4.2. Data Pre-processing: After gathering data from a variety of sources. Before using the model for training, a dataset must be pre-processed. Reading the acquired dataset can be the first stage of data pre-processing, which can then move on to data cleansing as shown in the Fig. 6.



```
preprocessing
    N   P   K  temperature   humidity        ph    rainfall label
0  90  42  43    20.879744  82.002744  6.502985  202.935536  rice
1  85  58  41    21.770462  80.319644  7.038096  226.655537  rice
2  60  55  44    23.004459  82.320763  7.840207  263.964248  rice
3  74  35  40    26.491096  80.158363  6.980401  242.864034  rice
4  78  42  42    20.130175  81.604873  7.628473  262.717340  rice
N              0
P              0
K              0
temperature    0
humidity       0
ph             0
rainfall       0
label          0
dtype: int64
(2200, 8)
RangeIndex(start=0, stop=2200, step=1)
   N  P  K  temperature  humidity  ph  rainfall  label
0  N  P  K  temperature  humidity  ph  rainfall  label
      N     P     K  temperature  humidity    ph  rainfall  label
0  2200  2200  2200         2200      2200  2200      2200   2200
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 2200 entries, 0 to 2199
Data columns (total 8 columns):
 #   Column       Non-Null Count  Dtype
---  ------       --------------  -----
 0   N            2200 non-null   int64
```

Fig. 6. Data pre-processing

4.3. Feature Selection: It is important that we select only those features that will be necessary to determine the type of crop to grow. For this, we have created a correlation matrix that shows the linear relationship of a feature with every other features. If features are highly correlated then that feature should be dropped, but as the below matrix that the features are not highly correlated with each other, hence it makes sense not to drop any of them and hence we will be using all of them to predict the type of crop to grow. The Fig. 7 shows correlation matrix for feature extraction.

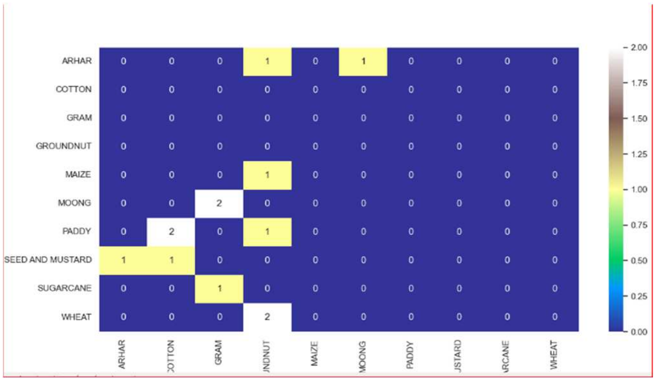


Fig. 7. Correlation Matrix for Feature Extraction

4.4. Classification of data: The crops are classified into summer, winter, rainy crops. After that we will predict the crops in the form of first cluster (Row-intercropping), Second cluster (Mixed-Intercropping) and Third cluster (Strip intercropping), Fourth cluster (Relay intercropping) as shown in the Fig. 8.

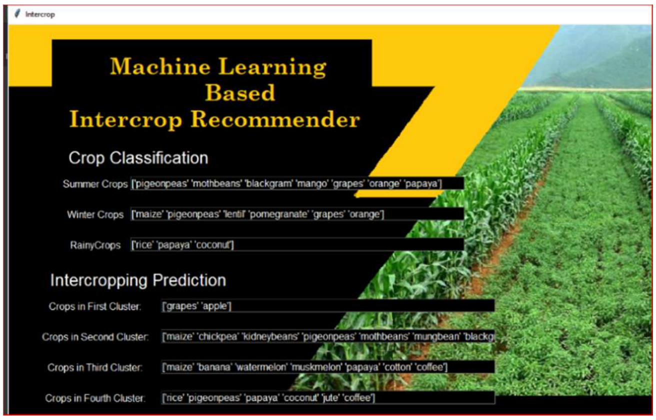


Fig. 8. Classification of Crops based Summer, Winter, Rainy crops

4.5 Machine Learning Algorithm for Prediction: Based on taught data, predictive machine learning algorithms have highly optimized estimates of what is likely to be the likely outcome [20]. We employ supervised machine learning algorithms such as the Gaussian Process Classifier, SVR, Decision Tree Classifier, Logistic Regression, and KNN, while for predicting the most suitable intercropping techniques, we use the Ridge Classifier, Logistic Regression, and KNN, Stochastic Gradient Descent.

Crop Prediction: We use input information like Crops to predict the specific crop that will be planted. Crop The external crop datasets are loaded to start the prediction procedure. After pre-processing the data, use KNN, Decision Tree Classifier, and Gaussian Process Classifier to train the models on the training dataset. While predicting the crop, the following factors are: Expected rainfall, soil PH, temperature, and humidity. The input parameter for the system is the crop which can be manually entered. The Fig. 9. shows a best crop yield based on Intercropping using KNN Classifier.

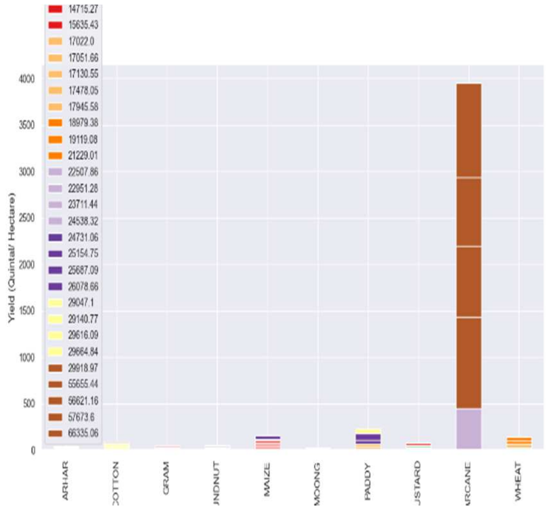


Fig. 9. Best Crop Yield Based on Intercropping using KNN Classifier

A model for summarizing crop predictions given the input parameter of choosing the crops ("Arhar and Gram") are tabularized as follows in the Table 1 which depicts the volume of Nitrogen, Phosphorous and Potassium in the different soil types which helps profitable yield of the crops with suitable weather parameters like temperature, humidity, rainfall.

TABLE I. SELECTING INPUT PARAMETERS IN ROW INTERCROPPING

Row Intercropping							
Soil Type	Nitrogen	Potassium	Phosphorous	Temperature	Humidity	Rainfall	Yield (kg/hectare)
Loam	90	42	43	20.87974	82.00274	202.9355	9.83
sandy loam	85	58	41	21.77046	80.31964	251.055	7.47
black cotton soils	60	45	44	23.00446	82.32076	263.9642	9.59

V. APPLICATIONS OF INTERCROOPING

The following are the most basic advantages of intercropping:

1.Increased profit: Even when the original crop fails, secondary crops offer higher returns and guarantee profit.

2. Protection of the cash crop: Intercropping serves a variety of purposes, including warding off or trapping pests, luring in beneficial insects, and providing shade from excessive sunlight or wind. Pest management lowers the need for chemical applications, saving money.

3.By growing leguminous intercrops, such as nitrogen-fixing plants, soil fertility is increased.

4.Reduced soil erosion.

VI. RESULTS

Fig. 10. Registration Page

The Fig. 10 shows the registration page of the proposed system which allows new users to register themselves into the system.

Fig. 11. Menu

The Fig. 11 is the menu of the system which gives various options like Read dataset, Pre-processing, Feature Extraction and many more.

The Fig. 12 shows when the user clicks on the predict option the page will redirects to the intercropping menu which gives options to select between different types of intercropping.

Fig.12. Types of Intercropping

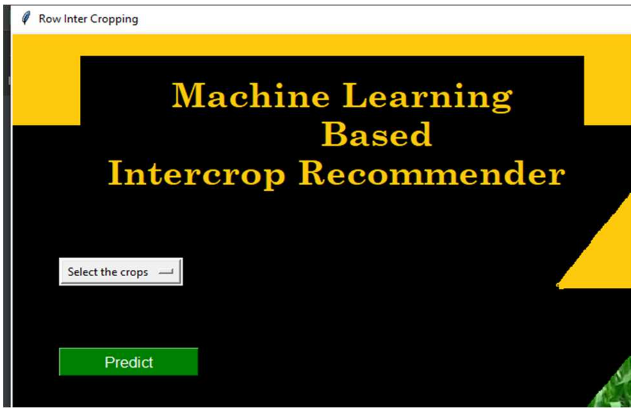


Fig. 13. Selecting Crops on Row Intercropping

The Fig. 13 shows the page which allows to select the crops in a particular type of intercropping.

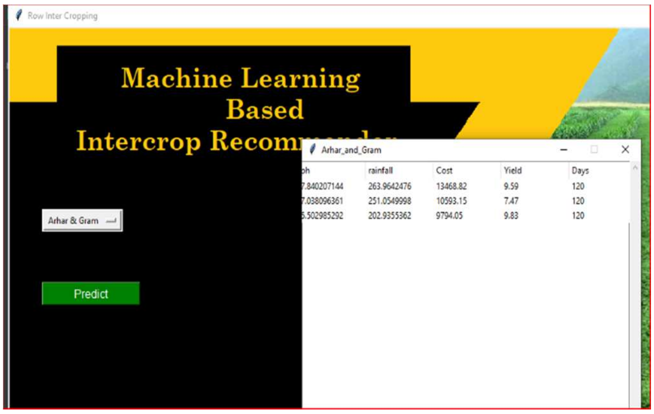


Fig. 14. Prediction of Arhar and Gram Yield Rate Under Row Intercropping

The Fig. 14 shows the output of the prediction carried out by the system for the crops.

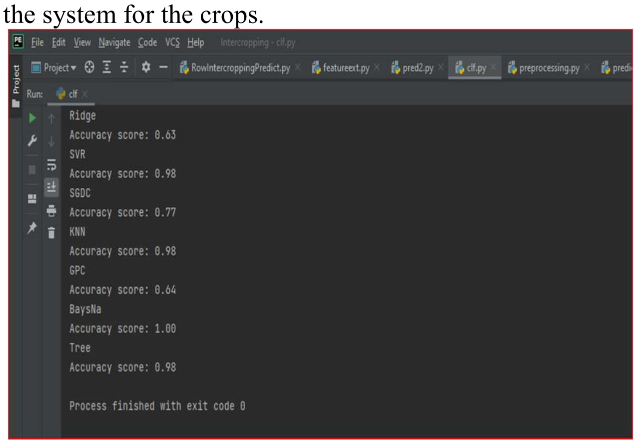


Fig. 15. Classification Algorithm Results

Fig. 15 shows the classification of the various algorithm results of proposed system.

VII. Conclusion

The System implemented yields to the conclusion that intercropping is the best option for the farmers to gear-up the income by increasing the production of the crop. Intercropping also helps in preserving resources and it gives a long-term viability. It gives the solution to double the income stream by cultivating more crops simultaneously. Based the classification of algorithms Naïve bayes has 1.00 accuracy and Decision tree, KNN and Support vector regression have 0.98 accuracy.

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