Prediction of crops according to the climate change using statistical machine learning methods

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Abstract: Climate change and agriculture are related to each other, both of which take place on a worldwide scale. Global warming would have significant impacts on conditions affecting agriculture, including temperature and precipitation. Thus climatic conditions are drastically changing. Hence the farmers cultivate the crop and sometimes due to changing climatic conditions, the crop fails and farmers are unable to earn from it. Excessive rains, water scarcity, drought are many of those things which are known in prior, preventions can be taken. Since this is not the case here in our country, the sudden climatic change affects a very important community of India, the farmers. The paper gives a brief study of important climatic features and its impact on crops. Machine Learning algorithms are applied to the data that has been collected from the India Water Portal (Karnataka State, India).Various classification machine learning algorithms are tested on the available data to get the best results.

1. Introduction

Agriculture is the primary supply of living for concerning fifty-eight percent of India's population. Throughout the 2018-19 crop year, food product production is calculable at a record of 283 million tonnes. In 2019-20, the government of the Asian nation is targeting foodgrain production of 291.1 million tonnes. The Asian nation is predicted to realize the formidable goal of doubling farm financial gain by 2022.

Poor communities in developing economies highly depend on climate-sensitive activities like agriculture for their livelihood and are particularly vulnerable to climate change.[1-5]. The agriculture sector in the Asian nation is predicted to get better momentum within the next few years because of accumulated investments in agricultural infrastructure like irrigation facilities, repositing, and cold storage. Moreover, the growing use of genetically changed crops can doubtless improve the yield for Indian farmers. The Asian nation is predicted to be independent in pulses within the returning few years because of concerted efforts of scientists to urge early-maturing kinds of pulses and also the increase in minimum support value. Agriculture could be a type of Associate in Nursing enterprise with an opportunity. Production of the crop depends on various factors like climate, geographical, organic, and financial components. Correct statistics relating to the character of the previous yields of the crop is very important to input that is helpful to farmers for decision-making techniques in producing the right crops. The advances in computing and data storage have provided most of the knowledge. The paper has been to extract the previous yield of crops and perceive the crops to be cultivated looking at the changing weather conditions. This task is aimed to investigate temperature change and so its impact on agriculture and crop production. The weather conditions square measure drastically ever-changing and so have created an enormous impact on agriculture in the Asian nations. Taking this into thought, the farmers want to support in understanding that crops ought to be taken by analyzing weather conditions. The project describes the analysis of weather conditions and their impact on ancient crops that square measure is taken. By analyzing the climate and former crops taken, prediction of the crops is done so the farmers get a plan concerning that crops ought to be taken according to the ever-changing weather conditions. This may facilitate them to survive their crops in an ever-changing climate.

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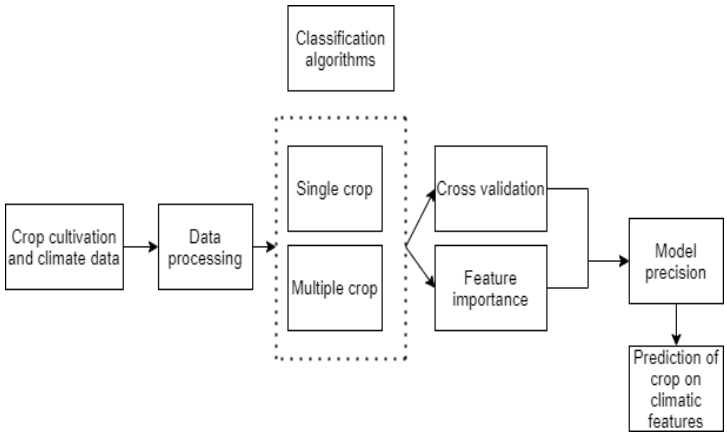

Fig.1: Working of prediction model through a flow chart

Precipitation, Temperature, Vapour Pressure, Reference Crop Evapotranspiration, and Potential Evapotranspiration are taken into consideration. Every element has different effects as follows.

2.Effect of temperature

One of the most influential factors in agriculture is temperature. Crops can grow only within a certain range of temperatures. Lower and upper limits of temperature are different for different species of crops. Temperature determines which crops can survive in a particular region. Temperature highly influences the germination of seeds. This phase of the crop shows low sensitivity to temperature. Different phases of germination are temperature dependent due to the biological process involved.

2.1 Cardinal temperature

Table 1: Cardinal temperatures for crops

Crop's seed	Minimum (°C)	Optimum (°C)	Maximum (°C)
wheat	4	25	32
soybean	9	30	41
Maize	9	33	42

The minimum, optimum, and maximum temperatures for the survival of each crop are called cardinal temperature. The Cardinal temperature of some crop seed germination is given. Temperature also affects the process of photosynthesis in crops. Very high temperatures and very low temperatures have adverse effects on the photosynthetic rate. The rate of photosynthesis increases with the rise in temperature from 5°C to 37°C beyond which there is a rapid fall (Mathaei 1904). In this particular range, the rate of photosynthesis is doubled every 10°C increase in temperature.

The rate of respiration increases with the rise in temperature till optimum temperature and beyond this, the rate decreases.

2.2.Effect of precipitation

Precipitation plays a vital role in the existence of crops. Without water, there is no photosynthesis and no existence of crops. Various essential elements being dissolved are transported to different parts of the crop. One of the important functions of water is transpiration cooling of the leaf surface, which protects the leaves from getting heated. Respiration and other nutrient uptake activities are regulated by water. The requirement of water for different crops differs considerably.

It has been reported that rainfall variability affects the production of traditional crops, increases crop disease incidents, and causes a drastic reduction in soil fertility[6-9]. Time, amount, form, and frequency of precipitation highly influence the crop. For example, heavy rainfall causes floods and loss of the crop. Also, hail causes loss to crops.

2.3.Reference crop evapotranspiration

Measured lysimeter evapotranspiration of a cool-season grass is taken as an index of reference crop. Efficient water management of crops requires accurate measurement of crop water requirements with accurate irrigation schedules. The United Nations Food and Agricultural Organization (FAO) in 1997 proposed a methodology for computing evapotranspiration. Reference evapotranspiration plays a vital role in determining the water requirements of the crop and irrigation schedules. Mathematical models are used to estimate evapotranspiration and water requirements of the crop. This helps to choose better water management practices. The precise estimation of water requirements is very necessary for irrigation scheduling.

The rate of evapotranspiration from a reference surface, not short of water, is called reference crop evapotranspiration and is denoted as ETo. The evapotranspiration model is limitedly applicable depending upon the input data. Data requirements for estimated ETo are: minimum and maximum of daily temperature, precipitation, pan evaporation, sunshine hours, wind speed, mean daily air temperature, potential evapotranspiration, and net radiation at crop surface. [10].

2.4.Potential evapotranspiration

Water is one of the important elements of plant growth and most of the needed water is stored in the soil. The availability of water depends on the water balance of the soil and this in turn depends on precipitation and evapotranspiration. The upper limit of evapotranspiration is potential evapotranspiration, which means the maximum possible water loss that takes place from a large vegetation-covered land surface with adequate moisture every time [11].

Potential evapotranspiration is one of the measures of plant water supply in relation to plant water demand. It is also used to indicate soil moisture conditions. Ep can be used to assess land-use feasibility and irrigation potential requirements for a selected crop. Studies have shown that the R-index (ratio of actual evapotranspiration (Et) and potential evapotranspiration (Ep)) near to 0.90 can be assumed as optimum water requirement and near to 0.60 can be considered as requiring irrigation for crop growth.

2.5.Vapour pressure

Humidity is one of the factors that affect crop water demand. This data is ideally necessary for the calculation of crop water demand or potential transpiration, defined as the amount of water required by the crop when it grows at zero water stress [12]. Vapour pressure deficit (VPD) has a significant effect on the water requirement for the crop to maintain optimal growth. However, the data required to calculate VPD on a daily basis is rarely available and therefore most of the models use approximations to estimate it.

4.Data for modeling

The data is collected from the India water Portal for the state of Karnataka. The data contains various features like precipitation, temperature, vapour pressure, reference crop evapotranspiration, and potential evapotranspiration. Along with this, the data has labels like crops including sugarcane, soybean, cotton, sunflower, etc. This data is used to predict the crops that can grow in given climatic conditions. As this is a classification problem, the decision tree classifier is applied to it to get the accurate prediction of the crop.

3. Classification predictive modeling

Classification predictive modeling is a task of mapping a function (f) from input variables (X) to discrete output variables (y). The output variables are called as labels or categories. The mapping function predicts the class or category for a given set of inputs. Here, the classification is divided into two classes, that is, crop is cultivated or not cultivated.

3.1.K nearest neighbors classifier for modeling

K nearest neighbors could be an easy rule that stores all out there cases and classifies new cases supporting a similarity live (e.g., distance functions). KNN has been employed in applied math estimation and pattern recognition already within the starting of the 1970's as a non-parametric technique.

Table 2: Results derived using KNN

Accuracy	96
Cross validation scores	0.94
Mean squared error	0.4

3.2.Random forest classifier for modeling

Random forests is a supervised learning algorithmic program. It is often used for classification and regression. It's conjointly the foremost versatile and straightforward to use the algorithmic program. A forest consists of trees. It's the same as the additional trees it's, the additional strong a forest is. Random forests create call trees on arbitrarily chosen information samples, get a prediction from every tree, and select the most effective answer by suggesting that of pick. It conjointly provides a fairly smart indicator of the feature importance.

Table 3: Results derived using Random forest classifier

Accuracy	94.6
Cross validation scores	0.95
Mean squared error	0.05

3.3.Support vector classifier for modeling

A Support Vector Machine (SVM) may be a discriminative classifier formally outlined by a separating hyperplane. In different words, given tagged coaching information (supervised learning), the algorithmic rule outputs Associate in Nursing optimum hyperplane that categorizes new examples. In 2 dimensional area this hyperplane may be a line dividing a plane in 2 components wherever in every category lay in either facet.

Table 4: Results derived using support vector classifier

Accuracy	95.5
Cross validation scores	0.94
Mean squared error	0.04

3.4.Decision tree classifier for modeling

Decision tree is a tree where internal nodes represent features. The branch here represents the decision rule and each leaf node depicts the outcome. Decision tree is easy to understand and can easily capture nonlinear patterns.

Table 5: Results derived using decision tree

Accuracy	100
Cross validation scores	0.94
Mean squared error	0

Taking into account all the classification algorithms, the decision tree gives nearest to accurate results depending on the input data. Considering all the crops that are present in the data (cultivated in

Karnataka State, India), the importance of every feature varies according to the crop.

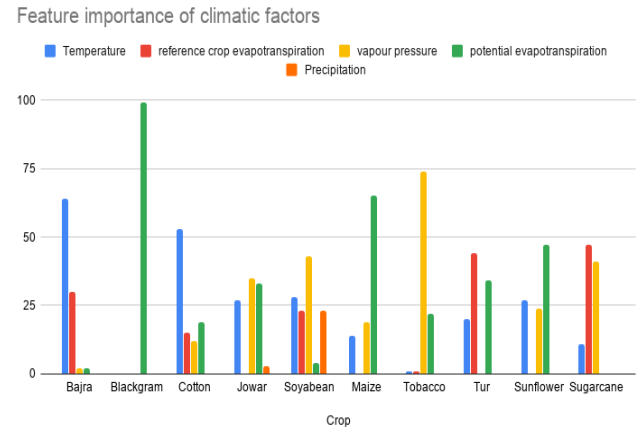

Fig. 2: Feature importance of climatic factors for various crops

The above graph depicts that every crop has different important features which affect crop life and growth. In the case of bajra, the temperature is the factor that affects the most whereas vapour pressure, potential evapotranspiration and precipitation affect the least. In the case of blackgram, potential evapotranspiration affects the most whereas other all factors affect the least. Considering cotton crop, temperature affects the most and vapour pressure and precipitation the least. In the case of jowar, most of the factors are equally important but reference crop evapotranspiration is still least important. Soybean crop also requires most of the factors equally. The highest requirement of factor potential evapotranspiration is seen in maize. In the case of tobacco, vapour pressure affects the most and other factors the least. Tur is highly affected by the reference crop evapotranspiration. In the case of sunflower, potential evapotranspiration is the factor that affects the most whereas, reference crop evapotranspiration and precipitation affect the least. Considering the crop of sugarcane. It is highly affected by reference crop evapotranspiration and vapour pressure.

4.Result and Discussions

4.1 Temperature Vs crops

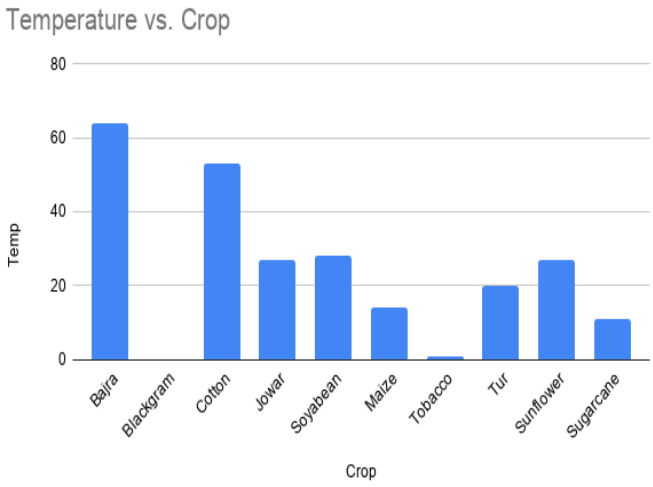

Fig. 3: Temperature Vs crops

The above graph tells us that the crop of bajra is highly affected by the temperature along with cotton. Blackgram and tobacco are the crops that are least affected by temperature.

4.2 Precipitation Vs crops

Precipitation is one of the factors that affects less to the crop. In the case of soybean, it affects the most and at some point in the case of jowar. Other crops are also affected by precipitation but at less amount but surely has some impact on the crops.

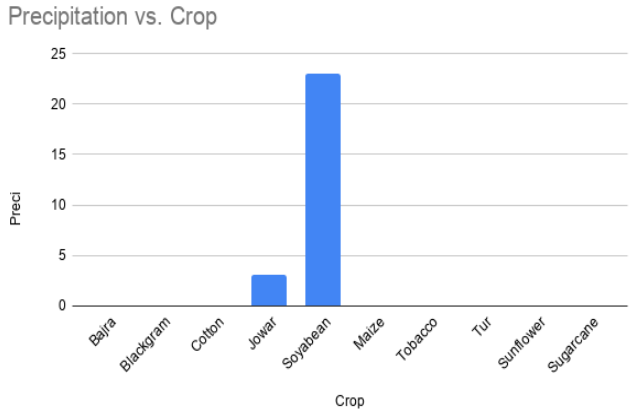

Fig. 4: Precipitation Vs crops

4.3 Reference crop evapotranspiration Vs crops

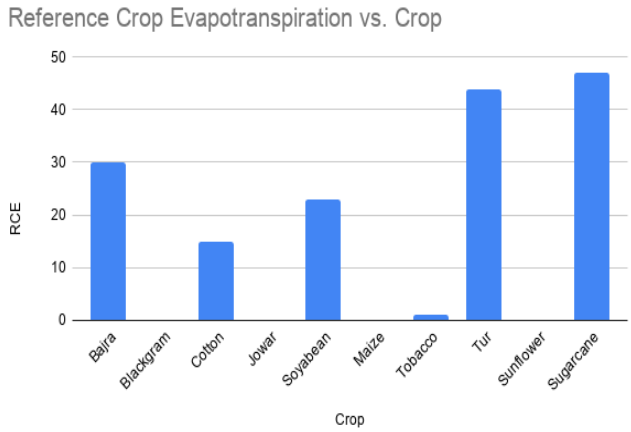

Fig. 5: Reference crop evapotranspiration Vs crops

Reference crop evapotranspiration also affects all the crops like sugarcane, tur, bajra, soybean, cotton, tobacco, blackgram, jowar and maize going in ascending order.

4.4 Potential evapotranspiration Vs crops

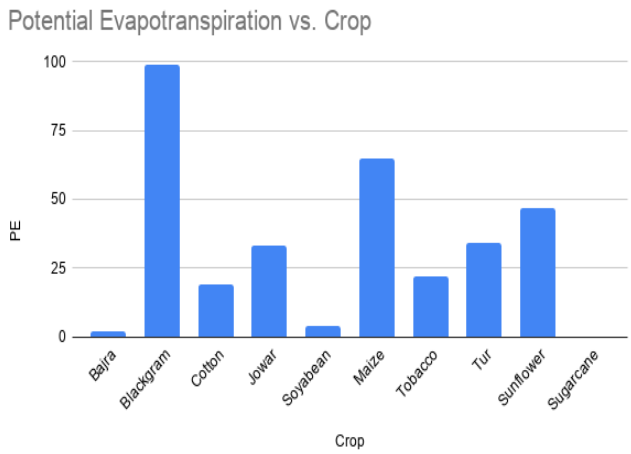

Fig.6 Potential evapotranspiration Vs crops

Blackgram is most affected by the potential evapotranspiration following with maize, sunflower and jowar. The crops that are least affected by potential evapotranspiration are sugarcane, bajra and soybean.

4.5 Vapour pressure Vs crops

Vapour pressure is another factor that affects crops. Tobacco is highly affected by vapour pressure along with soybean, sugarcane and jowar. The crops that are least affected by vapour pressure are tur, black gram and bajra.

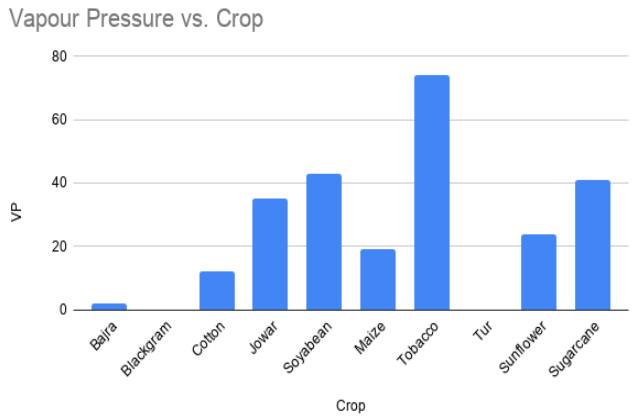

Fig.7 Vapour pressure Vs crops

5.Conclusions

The farmers now-a-days are cultivating the crops that they have been taking for a long time. As the climatic conditions are changing drastically, the crops that farmers are taking since long cannot always survive. Therefore, this paper would make them aware of the changing climatic conditions and prediction of the crops that should be cultivated. If farmers get an idea about these factors, it would certainly help them to cultivate the crops that would survive and not fail due to climatic conditions. Studying the previous agriculture data and current climatic conditions, the paper represents which crops can grow in particular climatic changes and what precautions would be taken to survive the crop.

Among the models that are used, the decision tree and KNN classifier has proved best for fitting the data whereas the support vector gives less errors along with the decision tree.

Having proposed this, there are certain conditions in which the crop may survive or may not survive. But still, the percentage of failure of crops would definitely reduce.

References

[1] Parry, Martin. Impacts, Adaptation and Vulnerability: Part of the Working Group II Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Summary for Policymakers-A Report of Working Group II of the Intergovernmental Panel on Climate Change and Technical Summary-a Report Accepted by Working Group II of the IPCC But Not Approved in Detail, Cambridge University Press for the Intergovernmental Panel on Climate Change, 2007.

[2] PK Nath, B Behera. A critical review of impact of and adaptation to climate change in developed and developing economies, Environment, Development and Sustainability, 13(1), 2011, 141–162.

[3] EH Allison, AL Perry, MC Badjeck. Vulnerability of national economies to the impacts of climate change on fisheries, Fish and Fisheries, 10(2), 2009, 173–196.

[4] WK Dumenu, EA Obeng. Climate change and rural communities in Ghana: Social vulnerability, impacts, adaptations and policy implications, Environmental Science & Policy, 55, 2016, 208–217.

[5] KR Hope. Climate change and poverty in Africa, International Journal of Sustainable Development & World Ecology, 16(6), 2009, 451–461.

[6] JJ Kashaigili, P Levira, E Liwenga, MV Mdemu. Analysis of climate variability, perceptions and coping strategies of Tanzanian coastal forest-dependent communities, American Journal of Climate Change, 3(2), 2014, 212–222.

[7] JE Olesen, M Trnka, KC Kersebaum. Impacts and adaptation of European crop production systems to climate change, European Journal of Agronomy, 34(2), 2011, 96– 112.

[8] P Kurukulasuriya, S Rosenthal. Climate Change and Agriculture: A Review of Impacts and Adaptations, 2013.

[9] C Kyei-Mensah, Adoption of an Ecosystem-Based Adaptation (EbA) Approach in the face of Climate Change: Improving livelihoods in fringe communities around the Worobong South Forest Reserve [Doctoral thesis], University of Ghana, 2017.

[10] R Kumar, V Shankar. Department of Civil Engineering, National Institute of Technology, Hamirpur (HP), India MK Jat Department of Civil Engineering, MNIT, Jaipur (Raj), India

[11] AYM Yao. Agricultural potential estimated from the ratio of actual to potential evapotranspiration. Agricultural Meteorology, doi:10.1016/0002-1571(74)90081, 13(3), 1974, 405–417. 8

[12] E Wang, CJ Smith, WJ Bond, K Verburg. Estimations of vapour pressure deficit and crop water demand in APSIM and their implications for prediction of crop yield, water use, and deep drainage. Australian Journal of Agricultural Research, 55(12), 2004, 1227. doi:10.1071/ar03216.