Machine learning approach to improve irrigation scheduling process through pan evaporation and evapotranspiration assessment based on real time climatic condition for Solapur district, Maharashtra.

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Abstract
Significant use of recent technology helps to enhance farming methods in agriculture to increase crop production. Improved water productivity is solution to increase the final crop production, ecosystem services, income, and better life hoods. Pan evaporation and evapotranspiration provide solution to achieve good quality and quantity crop production by analyzing required water consumption. The water lost from the soil surface is evaporation and water lost through the plant leaves is transpiration process. Different meteorological parameters study assists to estimate pan evaporation and evapotranspiration. This study is undertaken to develop a machine learning model which predict the present pan evaporation. Proposed study done for Sorghum crop, which is one of the important crops of many countries and staple food crop of India. The model is trained and tested on previous five-year continuous meteorological data for Solapur region. Several climatic parameters considered to estimate Pan evaporation and Evapotranspiration such as minimum and maximum temperature, wind speed, relative humidity, and rainy days. Three different regression techniques applied to estimate EPAN are random forest, linear regression and RANSAC (Random Sample Consensus). Performance analysis has been done on MSE, MAE and R2 score computation. The result analysis showed the performance of Random Forest and RANSAC model is superior to Linear regression model.
Keywords: Random Forest, RANSAC, Linear Regression, Pan Evaporation (EPAN), Evapotranspiration, Meteorological data.

1. Introduction

Innovative tools and technologies can help to improve water productivity by managing water resources. Water productivity is important to integrate crop production and water use. Productivity is the performance ratio of output to input. It is necessary to focus on the world's present increasing water scarcity issue, as because of increasing human population, water demands and erratic rainfall. Reducing unfavorable water usage can help to improve water productivity and to save water. Improving water productivity is essential to increase land productivity by reducing water cost with maximizing final yield for food security and profitability. It can also help to manage salinization, soil erosion and water logging. It is preferable solution to increase available irrigation water applicability for expanding irrigated area. [12]

The water scarcity prevents plant growth and development, similarly excess water can also have many adverse effects on plant growths. For the optimum water usage, scheduling of irrigation processes is important in farming to improve economic and agronomic feasibility. Improved irrigation scheduling process helps to increase yield quality and quantity with adequate water consumption. The scarcity of water at every growing stage of the crop influences final product grade and quantity.

This study has been done on the rabi sorghum crop for Solapur District, Maharashtra. ICAR established rabi sorghum research centre at Solapur, Maharashtra in 1991, to focus rabi sorghum research. The total area of the research centre is 18 hectares at Shelgi and Mulegaon two nearby locations in Solapur. The 8 hectares irrigated farmland in Shelgi, and 10 hectars rain fed farmland in Mulegao utilised for research centre. The soil type at research centre is semi-arid and the varieties of rabi sorghum used for the experiments are M-35-1(Maldandi), Yeshoda and Vasudha. [9]

It is important to identify crop water requirements at every growing stage. Evaporation Pan and evapotranspiration are the term which provide reliable water requirement estimation for growing plants in the farm. which can help to understand the present crop water requirements. EPAN data is generally limited, and in such a circumstance, theoretical estimates from available climatic data could be beneficial. [1]

A study has been done to predict present pan evaporation and to analyze evapotranspiration. Machine learning based model developed over previous five years continuous meteorological data using three different regression-based method. The climatic condition and soil type have significant relation in irrigation process scheduling aspect, which help to decide how much and when to irrigate the farm.

Rabi Sorghum

Rabi Sorghum is fifth most important cereal crop and for more than 500 million peoples from 30 countries are dietary staple. Sorghum crop is grown in both kharif and rabi season. Residual water-based cultivation and terminal drought (grain filling stage) occurrence are vital reasons of decreasing final rabi sorghum crop productivity [11]. Basically, in the month of September to February Rabi sorghum cultivation takes place. In standard meteorological week 38 to 41 sowing of the crop is being started. The rabi sorghum production in all districts of Maharashtra may be affected by unfavorable climatic condition. Because of uncertainty in the rain fall may effect on the crop growth such as ear emergence, grain setting, grain filling etc. optimum soil moisture and temperatures at important growth stages are necessary. This crop generally suffers from severe moisture stress, and it will make impact on the total crop production. In rabi sorghum crop growth life phases, the panicle (Primordial) initiation phase is the most important and sensitive phase for determining the product quality and quantity. This stage is between 26-35 days after sowing depending on the varieties of rabi sorghum. Irrigation and fertilization are required for 2-3 days of this stage. The extreme lower temperature (below 12^0C) and soil moisture stress during reproductive phase (flowering to hard dough stage) effects on grain filling, grain setting, grain number, grain size etc. and ultimately the yield [16]. The crop yield of rabi sorghum depends on different meteorological parameters, which is performed by correlation analysis in growing stage of crop.

Pan Evaporation (EPAN) and Evapotranspiration

It is important to determine the water requirement of the crop. Crops and environmental factors can help to decide crop water use. Meteorological data represent environmental factors and crop factors represented by crops varieties with its growth stages. Pan evaporation indicates evaporation rate over various meteorological parameters. Evaporation rate is high in sunny, hot dry and windy days and low in humid, calm, and cloudy weather. Productive crop water requirement can be estimated using temperature, wind speed, relative humidity, and solar radiation [14]. Pan Evaporation (EPAN) or Evapotranspiration (ET) dependent on different climatic parameters [13]. Pan evaporation provides favorable results for improved irrigation process scheduling. Evaporation is dependent on various climatic parameters. It affects crop evaporation and pan evaporation with combined effect of humidity, windspeed, temperature and sunshine on water consumption of crop [3].

Estimation of water loss from the soil and plant is called evapotranspiration. Main string of evapotranspiration is temperature, humidity, wind speed, and sunlight. An evapotranspiration standard estimation known as Reference Evapotranspiration (ET_0).

It can compute as,

$$ET_0=K_p*EPAN,$$

where: K_p: Pan coefficient.
EPAN : Pan Evaporation (mm/day)
ET_0 : Reference Evapotranspiration (mm/day).

Pan coefficient (K_p) depends on wind speed and relative humidity. It is directly proportional to relative Humidity (Rh) and inversely proportional to wind speed. The range is between 0.3 and 1.1. [15]

Evapotranspiration of crop (ET_c) can be considered by crop coefficient (K_c) and reference evapotranspiration (ET_0) as, $ET_c= K_c * ET_0$.

The crop coefficient (K_c) is specific crop water use and it depends on type of crop and growing stage of crop. It is used to determine water requirement of irrigation process. [3]

Machine Learning

Machine learning is the subset of Artificial Intelligence. It imports the knowledge from statistics and probability theory. It enables computer to learn by experience over training data and used to find out valuable underlying patterns from the complex data automatically. Intelligent systems can have qualities such as problem solving, reasoning, planning, decision making, inferences making and learning. We can put knowledge to the system in the form of data to develop intelligent model which can provide desired results. Such intelligent system can have ability to learn by itself with present data without explicit human intervention in the future, just like a human brain.

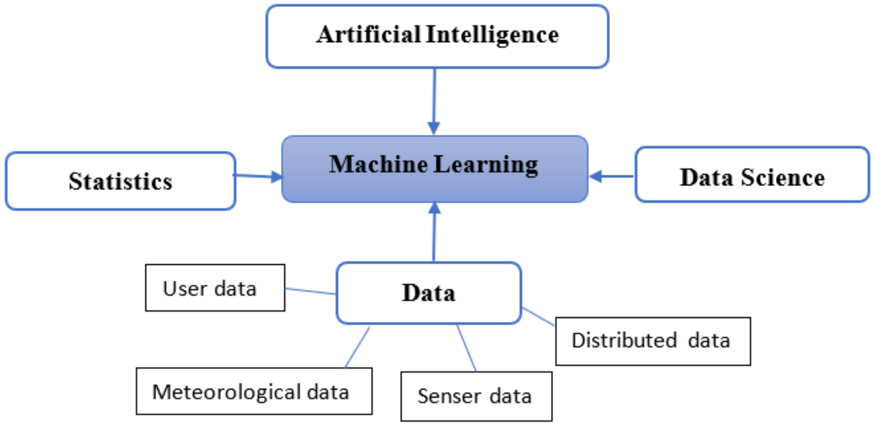

Figure 1: AI, ML, Data Science relationship, and various data sources.

The knowledge and hidden patterns use to perform different complex decision making and future event predictions from the problem. Predictive models of machine learning develop by mapping of the input variables to target variables. Data science term correlate all other terms such as Artificial Intelligence (AI), Machine Learning (ML), Deep learning to extract important insights from the available data. AI works on basis of machine learning and machine learning works on the data which used as part of the data science. So, AI allowing machine to think by machine learning terminology, which can give different tools and techniques with mathematical and statistical model. The data used to train machine learning model can be any user data, meteorological data, sensor-based data, or distributed data.
In this study machine learning model implementation has been done using three different supervised learning regression methods such as linear regression, random forest and RANSAC regression method.

2. Literature Review:

A. G. Smajstrla et al (2000), Irrigation process scheduling manage by estimating water use of the crop. Based on different climatic conditions water evaporation from the open pan of the growing crop farm can be considered estimating pan evaporation for water use of crop. Evaporation pan is useful for estimating daily water use rate of the crop for irrigation process. For determining irrigation time and water depletion quantity pan evaporation is important. Hence pan evaporation prediction is important for accurate irrigation scheduling process [16].

M. L. Chavan et al. (2010), In the present study reference crop evapotranspiration (ET_0) was estimated with the help of four methods namely Blaney-Criddle, Pan Evaporation, Priestly-Taylor and Hargreaves-Samani. The daily ET0 prediction capability of all these methods compared with FAO Penman – Monteith (FAO-56). This study has been done for southern hot and humid region of Konkan plateau, Maharashtra. By considering estimated ET0 with root mean square error, coefficient of regression and average deviation it is observed that Blaney-Criddle method is more accurate and reliable for ET0 estimation also, author mentioned that Hargreaves-Samani method can be consider as F-PM method substitute. [2]

Ahmet ERTEK (2011), The present study has been done to introduce pan evaporation importance for irrigation scheduling purpose, also to distinguish the pan coefficient (Kp), crop coefficient (Kc) and crop-pan coefficient (Kcp). The type of crop, growth stage of crop and climatic depends for understanding required water consumption (ETc) of crop. The linear relationship between water consumption of crop and evaporated water amount is observed in the study. In case of climatic changes and the technical terms consideration, pan evaporation method is more useful and quicker. It is concluded in the study that pan evaporation consideration is accurate for irrigation scheduling according to standard specification. It is determined by present meteorological data and important instead of direct water consumption calculation measurement of crop [3]

Rana Muhammad Adnan et al. (2017), To examine water balance, irrigation scheduling system design, water resource management and to estimate the crop growth and height evaporation parameter study is important. This study tells relationship between different parameters and the dataset is reduced using time series neural network with regression value R=83%. This study can also help to reduce the computational cost and time for evapotranspiration estimation. The parameters used for evapotranspiration estimation are minimum temperature, maximum temperature, wind speed, average temperature, rainfall, wind speed, relative humidity, and solar radiation. [4]

Isaya Kisekka et al. (2009) It is mentioned in the article that evapotranspiration method is beneficial for irrigation scheduling process. It is necessary to enhance the methods of water quantity and timing applied for supplement rainwater. For irrigation scheduling evapotranspiration method can increase efficiency. According to the plan water requirement and the soil properties this method helps to improve irrigation process. The author mentioned that to estimate evapotranspiration (ET_c) getting of the weather data is important for determining ET_0. Evapotranspiration is the combination of soil evaporation, rate of plant transpiration and water lost from plant root zone. [5]

Vargas Zeppetello et al. (2019), The Simple Land Atmosphere model (SLAM) developed in present study. This tool was developed to study in particular summertime temperature variability and in general land atmosphere interaction study. The observations show evaporation and soil moisture relationship observed for Budyko "two regimes" framework as it is limited by available soil moisture in dry climates and by radiation in wet climates. The summertime surface climate variability observations are used to evaluate the performance of the model at Atmospheric Radiation Measurement site in SGP. With restricted number of parameters SLAM designed to take more relevant summertime temperature variability.
Finding summertime variability of surface temperature over the land evaporation is important. [6]

D. C. lokhande et al. (2018), As sorghum is one of the main types of crops in southern and centra India arid and sei arid zone. The rabi sorghum cultivation is increasing over kharif sorghum, as because of hybrid improved varieties of rabi sorghum. Uncertainty, uneven and less monsoon rainfall affect crop production. The rabi sorghum grows on monsoon rainfall and some protective irrigation availability. But the inadequate water in growing phase of the crop production quantity and on quality. As rabi gain quality is superior to kharif hence the production takes higher price than kharif cultivation. To improve the production quality and quantity of rabi sorghum, in this study author introduced production technology for rabi sorghum with drip irrigation. The experiment was done on two different varieties of sorghum for three seasons. It is observed that there is significant difference in final production of yield comparatively with other irrigation schedules. Adequate amount of water in each growing phase of the crop helps to improve crop production quality and quantity also. [7]

N Seetharama et al. (1990), It is mentioned the present study that rabi sorghum is one of the most important cereals in India and over total sorghum production area rabi sorghum cover 40% of it. Proposed study based on literature and experience on both at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India and different Indian National programs. Based on the study suggestions are provided to increase the rabi sorghum crop production in future. Various environmental factors are mentioned in article which reduced the productivity like rainfall, solar radiation, temperature, open-pan evaporation, and saturation vapor-pressure deficit (SD), photoperiod, edaphic factors, soil water storage, soil nutrient content, soil cracking, insect, and disease problem. Similarly, some management factors like sowing date, irrigation, fertilization, plant density and row spacing are also effect on reducing rabi sorghum crop production. [8]

3. Proposed Study Model

3.1 Existing meteorological data:

Implementation of proposed study has been done on existing five years meteorological data provided by AICRP (All India Coordinated Research Project) Rabi sorghum research center, Solapur, Maharashtra. Analyzing of rabi sorghum crop growth and its relationship with climatic parameters has been done at agricultural research station. All meteorological data collection is done on daily basis at Zonal Agricultural Research Station, Solapur by observatory of Agrometeorology. The crop yield of rabi sorghum depends on different meteorological parameters, which are performed by correlation analysis in growing stage of crop like relative humidity parameter associated with crop reproductive phase. [9] Available data is in continuous form on daily basis with multiple parameters.

3.2 Data pre-processing / Data cleaning:

The raw data which is provided by the domain is not always ready to use for machine learning model development. The model performance depends on the data quality; hence data cleaning is one of the unavoidable steps of machine learning model development. Data cleaning is in terms of handling missing data, decimal mismatches, statistical noise, conflict in data and errors. Also, sometimes raw data may contain complex and nonlinear relationships which need to get reveal. Hence data preprocessing is important for data cleaning and to extract the feature from available data.

To estimate Pan Evaporation TMin (Minimum Temperature), TMax (Maximum Temperature), Rh1 (Relative Humidity 1), Rh2 (Relative Humidity 2), Wds (Wind Speed), EPAN (Evaporation Pan), RD (Rainy Day) are considered in the study, as many parameters are present in the existing dataset. In data preprocessing the available relative humidity Rh1 and Rh2 converted into single average relative humidity (RH), new Temp parameter (Temp) calculated by considering average of TMax and TMin temperature. In final data frame available parameters are Temp, Wds, RH, RD, EPAN. Missing decimals places are also corrected in data processing step.

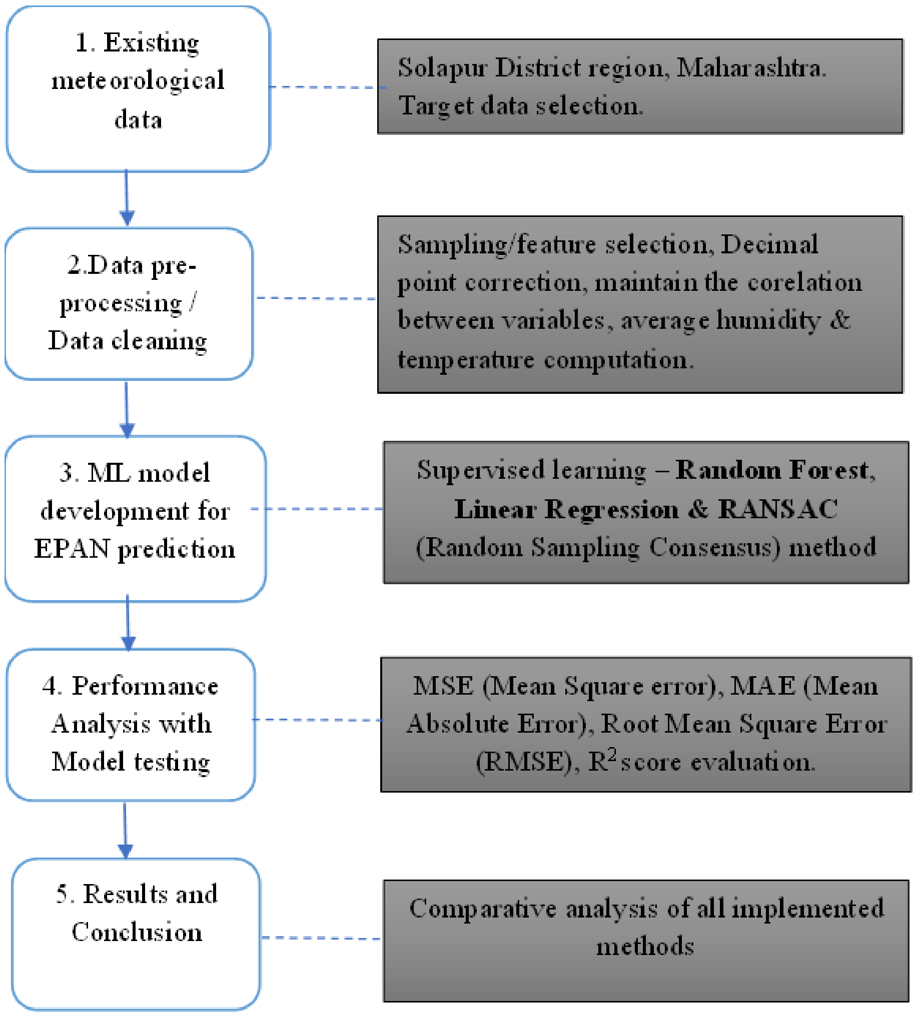

Figure 2: Proposed Study Model

3.3 ML model development for EPAN prediction:

The present study is based on machine learning regression analysis method as the available data and estimated results are in continuous form. Regression is a popular statistical analysis method in which models build relationships between one or more independent variable with dependent variable to predict the results. From present data frame Temp, Wds, RH and RD considered as independent variables and EPAN as dependent variable estimated based on independent variables. Regression supervised learning methods applicable for establishing variable relationships, prediction, time series modeling and forecasting. The study has been done on three different machine learning regression methods namely: Linear Regression, Random Forest and RANSAC (Random Sampling consensus).

Linear Regression:

This is one of the popular statistical analysis methods to predict continuous, real, or numerical variables, it shows linear relationship between dependent and independent variables. Variable relationship representation gives straight line slope.

Mathematical representation of linear regression is:

y=a0+a1x+c where, y=Dependent variable/Target variable
x= Independent variable/Predictor variable
a0=line intercept
a1=coefficient of linear regression
€= Random error

Random Forest

In supervised learning method random forest is used for regression as well as classification problem. It is an ensemble learning algorithm. Based on the different subsets of the given dataset multiple decision tree can be created for random forest analysis. Instead of one decision tree results, here average of all decision tree predicted results enhance results accuracy and reduce the overfitting problem.

The final predicted output is generated based on each tree predicted output. Each individual decision tree predicted output may or may not be correct but maximum majority votes from it can generate final predicted output. This is one of the most efficient algorithms to predict high accuracy output with less training time and efficient to handle large dataset.

Basic steps of Random Forest are:

1. Selection of K random data points(subset) from the training dataset.
2. Decision tree building for each subset.
3. Repeat steps 1 and 2 and create N number of decision tree.
4. Based on most of the results it will predict the results.

If the number of decision tree are more accuracy will also get increased.

RANSAC (Random Sampling consensus)

Random subset of inlier through training dataset fits a RANSAC model. Based on iteration model build sensible result with precise probability. This is non-deterministic algorithm and applicable for linear or non-linear regression. The determined inlier only estimates the final model.

Eliminating outliers from the training dataset by RANSAC algorithm, it takes Linear Regression algorithm for further analysis. RANSAC algorithm excludes outliers and includes inliers for training dataset. The datapoints which are significantly away from other points considered as outliers and the datapoints lies inside dataset considered as inliers. Outliers create impact on training dataset while learning the parameters and on coefficient of regression model also, hence this is foremost part of exploratory data analysis step to identify and remove outliers.

3.4 Performance Analysis with Model testing

In regression analysis method the vertical distance between datapoint and line which passes datapoints decides relationship and the performance of the model. Model optimization is important for finding the best model from different developed models.

Mean Squared Error (MSE): Finding the best fit line is the goal of linear regression to minimize the error by considering error between actual and predicted results. Least error represents the best fit model. Mean Squared Error (MSE) cost function used for accuracy mapping, it represents the average squared difference between predicted and actual values. Lower MSE represents more accuracy and zero represents complete accurate model. Mean squared error will never be negative as it is always squared the error and across complete dataset average it out.

Equation:

$$\text{MSE} = \frac{1}{N}\sum_{i=1}^{N}(y_i - \hat{y}_i)^2$$

Mean Absolute Error (MAE)

Absolute error is the difference between predicted results and the actual results and Mean Absolute Error is average of absolute error. It is also referred as L1 loss function. Formulating optimization problem by learning problems is one of the important regression model loss functions. This is one of the widely used popular model evaluation measurement technique.[10]

MAE= $|(y_i-y_p)|$ / n where- y_i: actual value
y_p: predicted value
n: total number of observations

Root Mean Square Error (RMSE)

Root Mean Square Error is square root of mean of square of all errors. The dependent and independent variable relationship strength is measured by the R squared method. Prediction quality can be measure by root mean square error, the difference between actual and predicted values calculated by Euclidean distance method. It is standard statistics measurement method to analyse performance of climatic, air quality and meteorological based model. Handling of the outliers is important concern with RMSE assessment [10].

Formula:

$$\text{RMSE} = \sqrt{\frac{\sum (y_i - y_p)^2}{n}}$$

$$\text{MAE} = \frac{|(y_i - y_p)|}{n}$$

y_i = actual value
y_p = predicted value
n = number of observations/rows

R^2 Score: It is variance for dependent variable by independent variable. This corelation tells relationship strength between dependent and independent variables. The value of R2 is 1 represent perfect positive corelation and -1 represents perfect negative corelation.

3.5 Results

To use adequate water for irrigation, Pan Evaporation based irrigation system with water balance concept provide optimum solution. The EPAN predicted parameter can be useful for the agronomist scientist in their research. The study has been done on three different supervised learning regression algorithms namely, Linear Regression, Random Forest and RANSAC. Model accuracy is measured by loss function to analyze predicted results with expected results. Loss function talks about model performance, higher value indicates low performance and low value indicates high performance. Different loss functions have their own properties. Accuracy of proposed model assess with four loss functions as, MSE, MAE, RMSE and R2 score. In RANSAC algorithm random sample selection is done with number of iterations, which can be considered as Max Trial. By default, it is 100 but in present study it is considered as 50. For random forest method maximum depth of the tree is 15, here depth of tree represents that while classifying the decision tree by creating sub samples from the actual data, when node cannot expand further or if leaves node contains less than min_samples_split samples. By default, min_samples_split is 2. Analyzing results of all three applied methods it is observed that Random Forest Regressor and RANSAC provide excellent results with small difference. These methods help to remove the outliers and it will impact on the model performance.

Table 1: Comparative analysis of implemented methods.

	RANSAC Regressor	**Linear Regression**	**Random Forest Regressor**
MSE	1.43246805	1.394310311	1.308196624
MAE	0.698885423	0.658688106	0.70059868
RMSE	1.196857573	1.180809176	1.143764234
R^2 Score	0.698885423	0.810577672	0.822276542

Conclusion

In this study, the authors aimed to develop a machine learning model to predict pan evaporation (EPAN) in order to enhance farming methods and increase crop production. They utilized meteorological data collected over a period of five years for the Sorghum crop in the Solapur region of Maharashtra, India. The data included parameters such as minimum and maximum temperature, wind speed, relative humidity, and rainy days. To preprocess the data, missing values, decimal mismatches, statistical noise, conflicts, and errors were handled. The relative humidity parameters were averaged to obtain a single average relative humidity (RH), and a new temperature parameter (Temp) was calculated as the average of the maximum and minimum temperatures. The final data frame consisted of Temp, wind speed (Wds), RH, rainy days (RD), and EPAN. Three machine learning regression algorithms, namely Linear Regression, Random Forest, and RANSAC (Random Sample Consensus), were employed for EPAN prediction. The performance of the models was evaluated using metrics such as Mean Squared Error (MSE), Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), and R2 score. The results indicated that both the Random

Forest Regressor and RANSAC models outperformed the Linear Regression model. These models demonstrated excellent performance with a small difference between them. The Random Forest model and RANSAC model were effective in removing outliers, which contributed to their superior performance. The findings of this study have implications for agricultural practices, particularly in the estimation of water requirements for irrigation. The predicted EPAN parameter can be valuable for agronomists and scientists in their research. The application of machine learning techniques, specifically Random Forest and RANSAC, can significantly contribute to improving water productivity and enhancing crop production in the agricultural sector.

Future Guideline

Predicted parameter EPAN can be the solution for irrigation process scheduling by considering the real time weather data parameters and crop evapotranspiration rate. By fetching real time climatical data through available API, proposed model can be useful for future irrigation decision making. Such a system can be the extension of this study and it will be also helpful for agricultural researchers to analyze the predicted parameters in other research. Application of analyzing evapotranspiration for adequate water consumption and final crop production provide practical application for better future decision making in agriculture. It will be also helpful to generate good quality data for water productivity.

This study has been done only on Rabi sorghum crop type but in future this study can be practicable for other crop type also.

Acknowledgement:

The author is grateful to Dr. B. D. Bhakare (HOD, Soil Science and Agril. Chemistry, MPKV, Rahuri) to provide the previous five years continuous meteorological data from Solapur District Dry-Land Research Center, Maharashtra. Dr. J. D. Jadhav (Head of Metrological dept. College of Agriculture, Pune (MPKV)) and staff for rendering their help by providing existing data and guiding to understand basic terminologies and needs.

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