

Application of data mining and statistical measurement of agricultural high-quality development

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Abstract. In this study, we aim to use big data resources and statistical analysis to obtain a reliable instruction to reach high-quality and high yield agricultural yields. In this regard, soil type data, raining and temperature data as well as wheat production in each year are collected for a specific region. Using statistical methodology, the acquired data was cleaned to remove incomplete and defective data. Afterwards, using several classification methods in machine learning we tried to distinguish between different factors and their influence on the final crop yields. Comparing the proposed models' prediction using statistical quantities correlation factor and mean squared error between predicted values of the crop yield and actual values the efficacy of machine learning methods is discussed. The results of the analysis show high accuracy of machine learning methods in the prediction of the crop yields. Moreover, it is indicated that the random forest (RF) classification approach provides best results among other classification methods utilized in this study.

Keywords: crop yield; data mining; machine learning; optimization; statistical analysis

1. Introduction

Production optimization of agricultural yields is of importance in terms of both quality and quantity. This subject has been the focus of many research studies in recent years. Due to vast amount of factors affecting the quality of the crops, data mining methods are widely utilized to extract the dependency of the crop yield on the factors such as raining, temperature, ground conditions, etc. The information obtained by data mining procedure could be utilized by a wide range of experts from farmers to businessmen for short- and long-term agricultural productions. Applying reliable information and the outcome of influencing factors' consequences in a continuous manner would result in better crop yield and maintaining ground quality (Dai and Safarpour 2021, Forsat *et al.* 2021, Ghamkhar *et al.* 2021, Khadimallah *et al.* 2021a, b, Kumar *et al.* 2021, Madenci 2021, Tlidji *et al.* 2021).

Maximizing crops yields is one of the main concerns for farmers and policy makers (Tian *et al.* 2021b). This subject has attracted many researchers in this field which uses multiple methods to acquire reliable predictions. In this regard, big data analysis plays a major role in the resolution of the matter. Priya and Geetha (2017) utilized dynamic programming to optimize different factors required for crop's growth in different stages. Moreover, they suggested that their approach could be employed for decision making on the type of the crop based on the soil type, raining and weather data in each region. Employing big data analysis by k-mean clustering method, Li and Niu (2020) proposed a new methodology to increase agricultural information

through internet of things (IoT) and real-time analyzing of the data by means of big data analysis. The IoT methodology are in close connection to data analysis in the field of agriculture (Lu and Neng 2010, Dlodlo and Kalezhi 2015, Radmannia and Naderzad 2018, Hsu *et al.* 2020, Li and Niu 2020, Vij *et al.* 2020, Tian *et al.* 2021a, Zhu *et al.* 2021, Cheng and Wang 2022, Satrio Wicaksono *et al.* 2022). Tantalaki *et al.* (2019) reviewed the articles using big data to optimized agricultural processes for the aim of precision agriculture. They argued that using machine learning methods could be a promising method in prediction of different approaches in agriculture but the method needs to be enhanced in some aspects.

Data mining consists of multiple method of statistical analysis and machine learning (ML) methods. Majumdar *et al.* (2017) presented a study on the applications of data mining in increasing agricultural productions. They utilized different data mining approaches as well as regression method to obtain the most effective factors in increasing crop yield. It is concluded that using data mining it would be possible to make crops more resilient to climate change. Kale and Patil (2019) proposed a system for aiding farmers make better economic decisions based on the crop cultivation strategies. In doing so, they utilized fuzzy logic method as well as machine learning method to make better decisions. Different classifier are employed by Vinoth and Elango (2021) to predict yield in paddy crops. They utilized data from different sources to collect required factors influencing crop yield. They claimed that using Naive Bayes classifier in machine learning predicts the yield more accurately in comparison to other classifiers. Jagtap *et al.* (2022) explored the applicability of several ML classification methods in the field of agriculture. Kamath *et al.* (2021) utilized random forest (RF) classifier to identify the importance of different parameters on the crop production.

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In this regard, they discussed the benefits of crop production prediction using data mining methods for farmers. On the agricultural trade, Yan (2021) presented data mining algorithm for decisions on the international agriculture trading. In the study, bidirectional encoder representations from transformers (BERT) is employed for data mining analysis. It was also claimed that the model could be utilized in the trade policy making in the field of agriculture.

Most of the data mining methods employed in the field of agriculture focus on the machine learning method and classification algorithms (Ayoub Shaikh *et al.* 2022, Khan *et al.* 2022, Sakthipriya and Chandrakumar 2022, Zheng *et al.* 2022b). Machine learning methods gives accurate and reliable results without need to conduct complicated simulations and numerical methods (Habibi *et al.* 2018a, 2019a, c, 2020, Hashemi *et al.* 2019, Moayedi *et al.* 2019, 2020, Al-Furjan *et al.* 2020, Alipour *et al.* 2020, Cheshmeh *et al.* 2020, Ghazanfari *et al.* 2020). In some cases, there are seen regression methods to analyze data and predict the crop outcomes. Using machine learning method is widespread in science and engineering fields. Using this approach, it is not necessary to engage the precise scientific rules to extract effects of each factors in the outputs and also reducing the experimental works (Amelirad and Assempour 2019, 2021, Bai *et al.* 2021, Guo *et al.* 2022, Li *et al.* 2022, Moradi *et al.* 2022, Zhang *et al.* 2022). The algorithm makes decision based on the behavior and general effects of each parameters on the desired output. Moreover, the importance of each algorithm could be determined by imposing slight change in each factor and observe its influence on the output. In this regard, Shorewala *et al.* (2021) utilized an image based machine learning algorithm based on convolutional neural networks (CNN) (Habibi *et al.* 2017, 2019a, c, Safarpour *et al.* 2018, 2019b, 2020, Alipour *et al.* 2020, Ebrahimi *et al.* 2020, Ghazanfari *et al.* 2020, Chen *et al.* 2022). The results indicated that ML method could precisely predict the weed-infected and weed density without need for numerous labeled images. Cunha *et al.* (2018) utilized satellite images of precipitation and soil properties to derive predictions for soybean/maize yields. The outcome of the study revealed that the machine learning technique could forecast the yields with similar error to other methods without need to normalized difference vegetation index procedure. Employing semi-parametric deep neural networks Crane- Drosch (2018) showed that prediction of the corn yield in US Midwest could be acquired with more accuracy than classical method and other non-parametric methods. In a different study on the agricultural machinery Waleed *et al.* (2021) utilized a machine learning approach to classify machineries based on the vibration and tilt measured by sensors. Using this method they accurately distinguished between different types of machinery. Carrot yield prediction were evaluated using random forest regression methodology by Wei *et al.* (2020). They utilized experimental and satellite data to train a machine leaning network and further employed this model to obtain carrot model. The most important effective parameters are obtained using Gini index and statistical parameters like correlation factor and mean squared error were used to observe model's performance.



Fig. 1 Map of the area of interest for crop yield analysis

In this study, we aim to use big data resources and statistical analysis to obtain a reliable instruction to reach high-quality and high yield agricultural yields. In this regard, soil type data, raining and temperature data as well as wheat production in each year are collected for a specific region. Using statistical methodology, the acquired data was cleaned to remove incomplete and defective data. Afterwards, using several classification methods in machine learning we tried to distinguish between different factors and their influence on the final crop yields. Comparing the proposed models' prediction using statistical quantities correlation factor and mean squared error between predicted values of the crop yield and actual values the efficacy of machine learning methods is discussed.

2. Methodology and data acquisition

2.1 Agricultural data

The soil type, raining information and temperature data from a region is acquired from different sources. Soil quality index (SQI) is calculated using simple additive method proposed by Amacher *et al.* (Amacher *et al.* 2007). In this indexing method the quality of soil fall into values between 0 to 26 using 19 chemical and physical properties of the soil. The formula of calculating SQI is given below (Ma *et al.* year, Zhao *et al.* year, Hou *et al.* 2021, Huang *et al.* 2021a, b, Jiao *et al.* 2021, Liu *et al.* 2021, Moradi *et al.* 2021, Xu *et al.* 2021, Dong *et al.* 2022, Luo *et al.* 2022, Michael *et al.* 2022, Wang *et al.* 2022b, Yang *et al.* 2022, Yu *et al.* 2022):

$$Total\ SQI = \sum \text{individual soil property index values} \quad (1)$$

In addition, the SQI value could be converted to percent value as follows (Fan *et al.* 2022, Wang *et al.* 2022a, Xia *et al.* 2022):

$$SQI, \% = \frac{Total\ SQI}{Maximum\ measured\ SQI} \times 100 \quad (2)$$

Moreover, the raining information in the total precipitation of the region in the agricultural year. The temperature is also the mean temperature of the cultivation

season to harvest of the crop. Agricultural crops in the region is typically wheat or chickpea. In the region under investigation the amount of crops yields during years of 2011 to 2021 is collected as tons per hectare for 47 sites. The region of the study has elevation of 1500m to 2300m. The precipitation ranges from 300mm/annual to 1100mm/annual. Moreover, mean temperature of the region in the range of 2011 to 2021 are varied from -2°C to 4°C. A plot of the region is depicted in Fig. 1.

2.2 Data mining

The method to obtain the most influential parameters on the wheat or chickpea yield is obtained through data mining approaches using machine learning techniques (Li *et al.* 2017, Yan *et al.* 2021, Zheng and Yin 2022, Zhu *et al.* 2022a). Therefore, several classification algorithm has been used in this study to name K-Nearest Neighbors (KNN), Support Vector Machine (SVM), Random Forest (RF) and Naïve Bayes (NB) as well as Multi Linear Regression (MLR). The efficacy of each method is evaluated to indicate best performance model in extracting data and following the crop yield model. Brief description of each method is given below (Habibi *et al.* 2016, 2018a, b, 2019b, d, e, Ebrahimi *et al.* 2019, Esmailpoor Hajilak *et al.* 2019, Pourjabari *et al.* 2019, Safarpour *et al.* 2019a, Zhu *et al.* 2022b):

2.2.1 K-nearest neighbor (KNN):

K-nearest neighbor (KNN) method is a simple and effective classification method which uses distance of new objects from previously defined clusters to categorize the new object. Therefore, this method is a supervised method working in Euclidian space. In the training process of the algorithm it is necessary to provide points' coordinates with their label. After training, the input of the model will be a point and the output is a label.

2.2.2 Support Vector Machine (SVM):

Support Vector Machine is a supervised method similar to the KNN method. In this method a border between two different clusters is defined and new points are labeled based on their position with respect to this borderline (Shariati 2008, Shariati *et al.* 2011b, 2018, 2019b, 2020b, Hamidian *et al.* 2011, Shah *et al.* 2015, 2016a, b, Khanouki *et al.* 2016, Toghroli *et al.* 2017, 2018, 2020, Chen *et al.* 2019, Li *et al.* 2019, Naghipour *et al.* 2020b, Razavian *et al.* 2020, Hosseini and Toghroli 2021, Mehrabi *et al.* 2021).

2.2.3 Random Forest (RF):

Random Forest algorithm is also a supervised classification and regression method which utilized decision tree to produce results. This method performs better in classification problems. The random forest method has several trees. In this method, different trees are trained by random selection of data from provided data set. Each tree is trained independently. A new data provides as output is fed into all trees and outputs of all trees are aggregated to obtain the final results (Khanouki *et al.* 2016, Shah *et al.* 2015, 2016a, b, Shariati *et al.* 2018, 2020b, Naghipour *et al.* 2020b, Mohammadhassani *et al.* 2013, 2014, Heydari and

Shariati 2018, Shariati *et al.* 2018, Chen *et al.* 2019, Luo *et al.* 2019, Xie *et al.* 2019, Razavian *et al.* 2020,).

2.2.4 Naïve Bayes (NB):

Naïve Bayes is a combination of algorithms based on probability principles to make a classification decision (Zheng *et al.* 2022a). It utilized Bayes' theory to calculate the probability of a certain output and Naïve assumption to observe independency between different features (Safa *et al.* 2019, Shariati *et al.* 2019a, 2020a, e, Suhatriel *et al.* 2019, Jahandari *et al.* 2021).

2.2.5 Multi Linear Regression (MLR):

Multi Linear Regression is a method of calculating a dependent variable based on the independent variable by fitting linear equations (Arabnejad Khanouki *et al.* 2010, Shariati *et al.* 2010, 2011a, 2012a, b, c, d, 2013, 2014a, b, 2015, 2016, 2017, 2020c, d, f, Shariati 2013, Ali 2012, Abdolrahim 2012, Khorramian *et al.* 2015, Shah *et al.* 2016c, Tahmasbi *et al.* 2016, Khorami *et al.* 2017a, b, Hosseinpour *et al.* 2018, Ismail *et al.* 2018, Nasrollahi *et al.* 2018, Paknahad *et al.* 2018, Wei *et al.* 2018, Zandi *et al.* 2018, Davoodnabi *et al.* 2019, Naghipour *et al.* 2020a, Nouri *et al.* 2021). Therefore, this method is also a supervised method and the model is regarded as trained when the coefficient of each independent variable is calculated. All the above mentioned classification methods are defined in Scikit-Learn package in Python (2011). Therefore, we will use this package in Python to compare the results.

3. Results and discussion

3.1 Collected data between 2011 and 2021

In this section the results of the collected data and machine learning analysis is presented. In Fig. 2 the effects of different factors on the wheat production is presented. As seen, the effect of average precipitation in each year has a direct effect on the wheat production. On the other hand, effects of SQI and temperature could not be clearly resolved. However, it is safe to say that increase in temperature could result in higher production. Moreover, general trend in the SQI graph shows that increase in the quality of soil also leads to increase in the wheat production.

Similarly, in Fig. 3 the effects of different factors on the chickpea production is shown. As can be observed, the effect of average precipitation in each year also has a direct effect on the chickpea production. Moreover, effects of SQI and temperature are not conclusive. However, it is safe to say that increase in temperature could result in higher production. In addition, general trend in the SQI graph shows that increase in the quality of soil also leads to increase in the chickpea production.

3.2 Machine learning algorithms

Different machine learning algorithm as described above are employed to predict wheat and chickpea production per hectare and to find the most effective factor

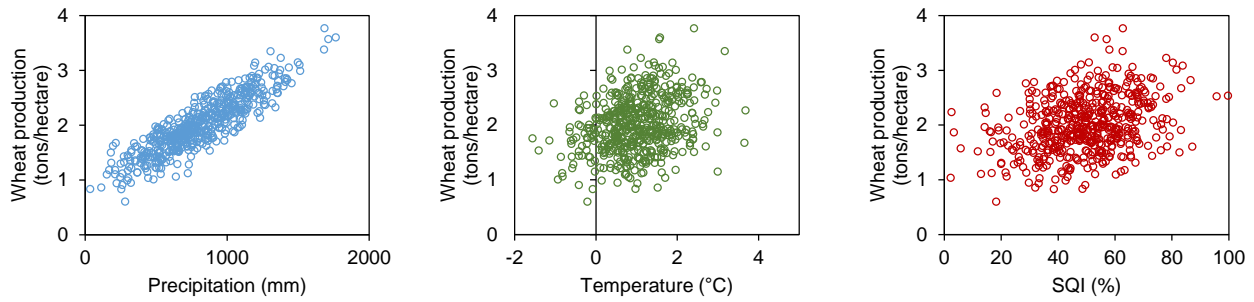


Fig. 2 Precipitation, temperature and SQI data of 50 sites during 2011 to 2021 and corresponding wheat production per hectare

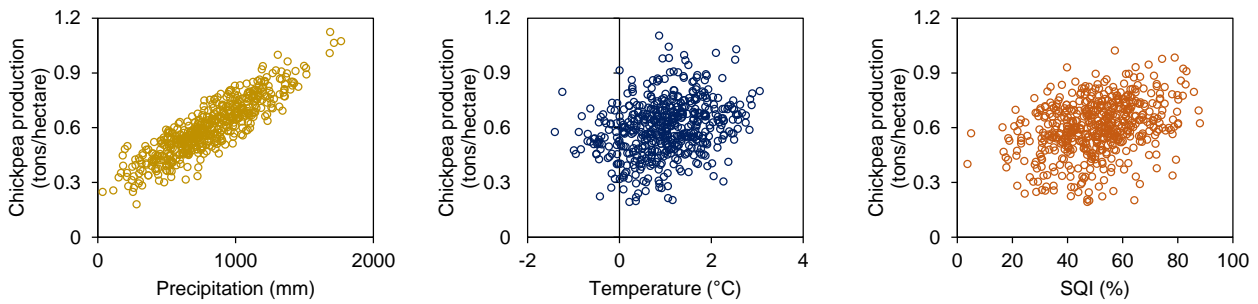


Fig. 3 Precipitation, temperature and SQI data of 50 sites during 2011 to 2021 and corresponding chickpea production per hectare

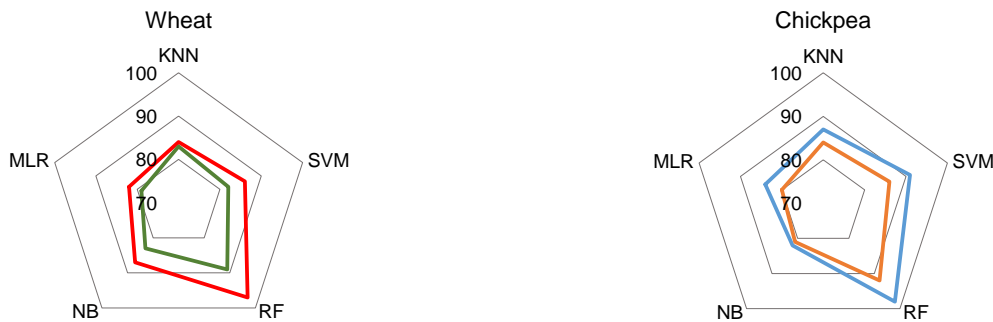


Fig. 4 Spider chart for comparison of train and test correlation factor between actual data and predicted data

among considered features here on the production. Moreover, based on the precipitation, temperature and SQI we try to suggest farmers to cultivate which crop between wheat and chickpea. The training process in supervised algorithms is performed using 80% of the available data. The remaining 20% is used for the purpose of testing. In Fig. 4, the correlation factors for both train and test predictions and the actual values are presented for different ML algorithms. As could be observed, the random forest method presented best results in both train and test sections in the case of both wheat and chickpea. Therefore, it is the most appropriate method in prediction such crop production forecast. However, this method is unable to predict the most influential factor on the crop production. Finding the most influential feature on the either wheat or chickpea production could be conducted utilizing multi-linear regression methodology. In fact, the coefficient to of each factor determines the effectiveness of that factor. In the MLR analysis is it found that the most important factor is precipitation for both wheat and chickpea.

An important results of this kind of analysis could be the suggestion of crop cultivation in each year. Thus, in what follows a systematic approach is presented to make such suggestions. Until now, it is realized that the most important factor is increasing production is precipitation in both cases of wheat and chickpea and the least important is the mean temperature. In Fig. 5, the normalized production of wheat and chickpea is depicted for the same conditions in terms of precipitation, temperature and SQI. The normalized value is defined as follows:

$$\text{Normalized value} = \frac{\text{Actual production}}{\text{Maximum available production value}} \quad (3)$$

In this regard, it could be concluded that in each condition, i.e., each point on the graph, if the point lays below $y = x$ line (blue line) the condition is in favor of chickpea cultivation. On the contrary, if the point located above the line, it is suggested that wheat be cultivated that year.

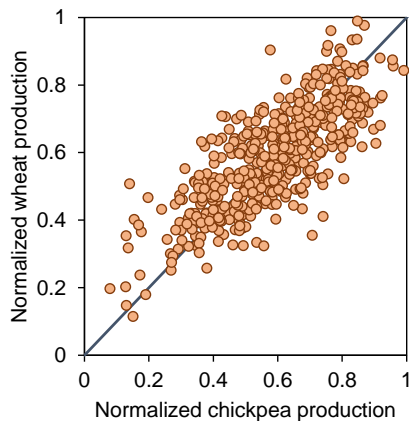


Fig. 5 Decision graph for cultivating wheat or chickpea

4. Conclusions

In this study, we aimed to use big data resources and statistical analysis to obtain a reliable instruction to reach high-quality and high yield agricultural yields. In this regard, soil type data, raining and temperature data as well as wheat production in each year are collected for a specific region. Using statistical methodology, the acquired data was cleaned to remove incomplete and defective data. Afterwards, using several classification methods in machine learning we tried to distinguish between different factors and their influence on the final crop yields. Comparing the proposed models' prediction using statistical quantities correlation factor and mean squared error between predicted values of the crop yield and actual values the efficacy of machine learning methods is discussed. The results of the analysis could be encapsulated in the followings:

- show high accuracy of machine learning methods in the prediction of the crop yields. Moreover, it is indicated that the random forest (RF) classification approach provides best results among other classification methods utilized in this study.
- In the MLR analysis is it found that the most important factor is precipitation for both wheat and chickpea.
- A methodology for choosing between cultivation of wheat or chickpea is suggested.
- The random forest method presented best results in both train and test sections in the case of both wheat and chickpea.

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