JCBI
Journal of Computing & Biomedical Informatics
ISSN: 2710 - 1606
Volume 06 Issue 01
2023

Research Article
https://doi.org/10.56979/601/2023

Soft Computing-Based Climate Change Monitoring System Using Multi- Sensor Dataset

Laraib Noor[1], Salman Qadri[1*], Sami Ullah[1], and Syed Ali Nawaz[2]

[1]MNS-University of Agriculture, Multan, Pakistan.
[2]Department of Information Security, The Islamia University of Bahawalpur (IUB), Bahawalpur 63100, Pakistan.
[*]Corresponding Author: Salman Qadri. Email: salman.qadri@mnsuam.edu.pk

Received: November 11, 2023 **Accepted:** November27, 2023 **Published:** December 05, 2023

Abstract: Conventional agricultural systems are unable to meet both global food safety issues and the demands of the human population. These difficulties are a result of farmers' poor crop planning. To handle air, dirt, water, etc., a digital twist is required. New farming strategies need to be developed to address the consequences on the air, land, water, etc. To mitigate the potential consequences of climate change, "climate-smart agriculture" (CSA) is recognized as a viable and sustainable agricultural system. The objective of this study is to forecast crop production. Farmers would select the crop that will produce greater amounts based on the local climate. Making critical decisions will also be easier for farmers if they have advanced knowledge of the crop output. The results of this research will help farmers forecast crop yields based on soil and climate factors. With the use of the proper soft computing approaches, the model discovers the association between variables such as crop production and characteristics like rainfall and soil type. The best crops can be selected by farmers with its assistance, and the agricultural businesses will benefit from these forecasts as well.

Keywords: Climate-smart agriculture; Soft computing; Crop yield.

1. Introduction

The best utility sector is agriculture, especially in developing nations like Pakistan. While farming contributes only 18% of the Gross Domestic Product (GDP), it is the primary source of income for a significant portion of the country's population. Due to unnatural climatic changes, prediction is being depleted, which will harm the economy by producing a low yield. By utilizing machine learning, one of the most cutting-edge technologies in crop prediction, this research assists farmers by guiding them in sowing reasonable crops [1].

The examination of the primary soil characteristics, such as organic matter, vital plant nutrients, and micronutrients that influence crop development, and determine the appropriate proportion link between those characteristics using supervised learning [2].

Depending on the geography and irrigation technique, climate change has different effects on agricultural productivity. Although it might increase agricultural yield, irrigated region expansion may be detrimental to the environment. Numerous crops are probably going to have decreased yields as a result of shorter growing seasons. It is predicted that the total output of wheat, rice, and maize will decrease if both the temperate and tropical areas experience a 2 °C warming. Because tropical crops are still closer to their high-temperature optimum and are thus more vulnerable to high-temperature stress during high temperatures, tropical regions are generally more impacted by climate change [3].

A non-linear method is needed to analyze the connection in order to illustrate the interactions between the factors impacting crop output. Due to the complexity of the factors impacting agricultural output, a. linear methods like linear regression were thought to be insufficient to illustrate the interactions of the components and crop yield. An alternative to conventional linear regression methods for estimating agricultural yield was thought to be ANN [4]. Pakistan urgently must find a compromise between economic growth, environmental sustainability, and energy security [5].

For a nation where almost 50% of the people is engaged in farming, it is a severe problem when farmers fail to select the crop that is best suited for their land using conventional and non-scientific methods. Potential researchers are prevented from working on building country case studies by their availability and access of accurate and current information [6]. The crop predictive model for formers is presented in this suggested work and is based on the SVM algorithm. To avoid losses for farmers and boost productivity, it is required in this task to examine the income of the crop. For classification, the SVM algorithm is considered. Accuracy and a misclassification rate are computed to evaluate the efficacy of the suggested approach [7].

In this study, they provide a technique for estimating the functional characteristics of soil samples. With the help of the Africa Soil Property Prediction dataset, we tested our algorithm, and the outcomes seemed good [8]. Numerous sensors are used by this system to track the soil's pH, temperature, humidity, moisture content, and NPK nutrients. Among these sensors are those for pH, soil temperature, and soil moisture. The microcontroller retains the information gathered by these sensors and uses machine learning techniques such as random forest to evaluate and produce suggestions for the growing of the best suitable crop [9].

In Pakistan, crop productivity is low when compared to developed economies. This is because rural people have limited savings or low-income levels due to tiny landholding sizes, the use of antiquated farming methods, subpar irrigation systems, and poor adoption of modern agricultural technologies [10]. Artificial neural networks, the k-nearest neighbors classifier, decision trees, the Bayesian classifier, and the Support Vector Machine (SVM) algorithm are just a few of the effective classification methods that have been studied in the literature. SVM is among these methods' most well-known methods for enhancing the anticipated outcome [11]. There is a need to develop policy solutions that take into account crop- and location-specific potential hazards and possibilities related to climate change in Ethiopia as a result of the heterogeneities in the consequences of climate shifts on crop yields across various altitudes [12]. Remote sensors collect environmental data, which is then analyzed by algorithms and statistical data that can be understood and used by farmers to manage their fields and make decisions [13].

The objective of this study is to develop a climate-smart crop production system that aims to boost agricultural productivity and efficiency, all the while mitigating the risks of crop failure. Our primary objective is to use resources as efficiently as possible while also reducing the environmental impact of farming operations. To promote sustainability in agriculture, this research intends to encourage the adoption of crops most suitable to the local environment. This strategy also supports cutting back on the use of artificial fertilizers and pesticides, both of which support environmental preservation. To tackle the urgent problems caused by climate change by developing a comprehensive strategy for sustainable agriculture, helping to produce crops that are adaptable to the effects of climate change, and increasing yields by utilizing cutting-edge soft computing techniques.

- Creating a climate-smart agricultural production system.
- Using soft computing to increase crop yield.

2. Materials and Methods

2.1. Study Domain

We used a comprehensive dataset that integrated soil properties gathered over the previous five years with meteorological data from the "AWS-MNS-University of Agriculture Multan, Pakistan" weather station to achieve these aims. An important contribution of this dataset was the development of a system for recommending crops. Essential climatic factors including humidity, rainfall, temperature, and soil qualities like pH were included in the data. Because these data were gathered continuously throughout time, an accurate representation of the soil and climate conditions was guaranteed. The dataset, which encompassed a range of seasons and years from 2018 to 2022, provided insightful information about soil and climatic conditions. The collection included timestamps that indicated the location and time of each measurement's recording. Our dataset was arranged tabularly, with each row denoting a distinct measurement made at a given time and place. The humidity, temperature, rainfall, and soil pH were among the data values that were given as numerical numbers. We carried out crucial preprocessing procedures to guarantee the consistency and quality of the dataset. This required dealing with missing numbers, bringing the data into compliance, and locating and eliminating anomalies. These actions were essential to getting the dataset ready for soft computing methods.

2.2. Dataset

The dataset was arranged tabularly, with each row indicating a distinct measurement made at a given time and place. The data values recorded were temperature, humidity, rainfall, and soil pH, all as numerical values. We carried out crucial preprocessing procedures to guarantee the consistency and quality of the dataset. This required dealing with missing numbers, bringing the data into compliance, and locating and eliminating anomalies. These actions were essential to getting the dataset ready for soft computing methods. The collection included timestamps that indicated the location and time of each measurement's recording. The dataset was arranged tabularly, with each row denoting a distinct measurement made at a given time and place. Temperature, humidity, rainfall, and soil pH were all represented as numerical values in the data. We carried out crucial preprocessing procedures to guarantee the consistency and quality of the dataset. This required dealing with missing numbers, bringing the data into compliance, and locating and eliminating anomalies. These actions were essential to getting the dataset ready for soft computing methods. An important contribution of this dataset was developing a cropping system of suggestions. Essential climatic factors including temperature, humidity, rainfall, and soil qualities like pH were included in the data. Because these data were gathered continuously throughout time, an accurate representation of the soil and climate conditions was guaranteed. The dataset, which encompassed a range of seasons and years from 2018 to 2022, provided insightful information about soil and climatic conditions as shown in Figure 1.

Table 1. Min-max temperature required for crops

Crop name	Minimum temperature ºC	Optimum temperature ºC	Maximum temperature ºC
Rice	10	32	36-38
Wheat	4.5	20	30-32
Maize	8-10	20	40-43

The minimum and maximum temperatures required for crops are given in Table 1.

Wheat	Min	Max	Avg
N	75	110	90
P	40	80	60
K	10	30	20
Temp	20.09	33.98	25.76
Humidity	50.02	59.99	49.40
Ph	6.01	6.98	7.09
Rainfall	76.73	162.78	150.79

Rice	Min	Max	Avg
N	60	100	81
P	35	60	48
K	35	45	40
Temp	20.05	26.93	24.03
Humidity	80.12	84.97	43.27
Ph	5.01	7.87	6.68
Rainfall	182.05	298.95	240.75

Cotton	Min	Max	Avg
N	100	140	120
P	35	60	47
K	15	25	20
Temp	22.01	25.98	24.47
Humidity	75.01	84.88	80.43
Ph	5.8	7.99	7.00
Rainfall	60.65	99.98	80.11

Maize	Min	Max	Avg
N	60	100	81
P	35	60	47
K	15	25	20
Temp	18.02	26.87	22.45
Humidity	55.43	74.09	65.21
Ph	5.51	7.02	0.51
Rainfall	60.09	102.33	81.79

Figure 1. Crops Dataset

The temperature ranges that are essential for the effective growing of different crops are shown in Table 1. Understanding these temperature requirements is vital for optimizing agricultural productivity. Rice thrives within a temperature range where the minimum required is 10ºC, the optimum temperature for growth is around 32ºC, and it can tolerate maximum temperatures within the range of 36 to 38ºC. Wheat, another staple crop, has different temperature requirements. Its minimum temperature requirement is 4.5ºC, while the optimal temperature for growth is around 20ºC. Wheat can tolerate maximum temperatures within the range of 30 to 32ºC. Maize, commonly known as corn, requires minimum temperatures ranging from 8 to 10ºC. Its optimum temperature for growth is similar to wheat at around 20ºC. However, maize exhibits a broader tolerance for maximum temperatures, ranging from 40 to 43ºC.

2.3. Method

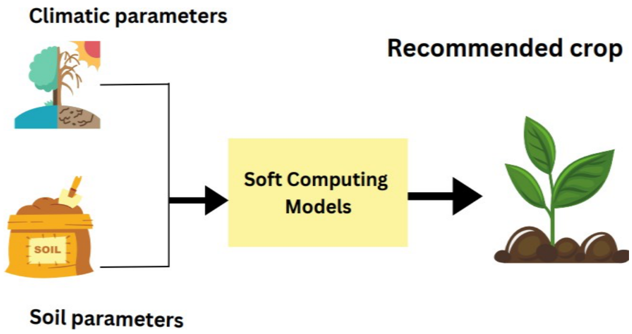


Figure 2. Proposed Methodology

Figure 2 shows a soft computing-based crop recommendation system that uses multi-sensor data on climatic and soil factors. When data is accessed, the next phase is the interpretation of data to make useful decisions about which crop is to be cultivated in this environment. This will help to generate a good crop yield for that specific area. The goal of this study is to develop a cutting-edge, environmentally friendly strategy that can increase agricultural output and resilience while minimizing environmental effects. The research will strive to discover appropriate crops and crop types that can survive in the current environment, optimizing resource usage efficiency and reducing hazards associated to climate change by a thorough review of climatic data, agricultural practices, and technology improvements. This study intends to contribute to the creation of a strong and forward-looking crop production system capable of encouraging food security and sustainable agricultural practices in the face of a changing environment by using adaptive techniques and contemporary agricultural technologies.

2.3.1. To Develop a Climate-Smart Crop Productions system

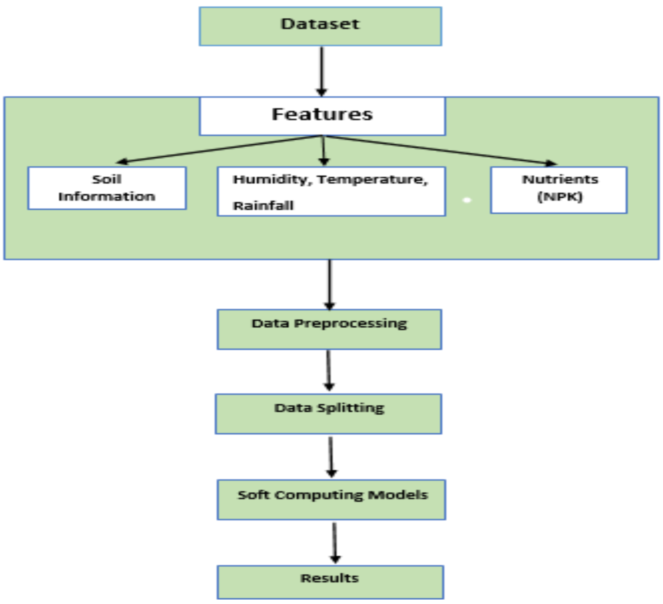


Figure 3. Proposed System

Figure 3 demonstrates a climate-smart crop farming system is defined as one that makes use of a range of techniques and technologies to enhance agricultural operations in response to changing climatic circumstances. Using soil and climate datasets, the system combines preprocessing techniques, data-splitting strategies, computational models, and result analysis.

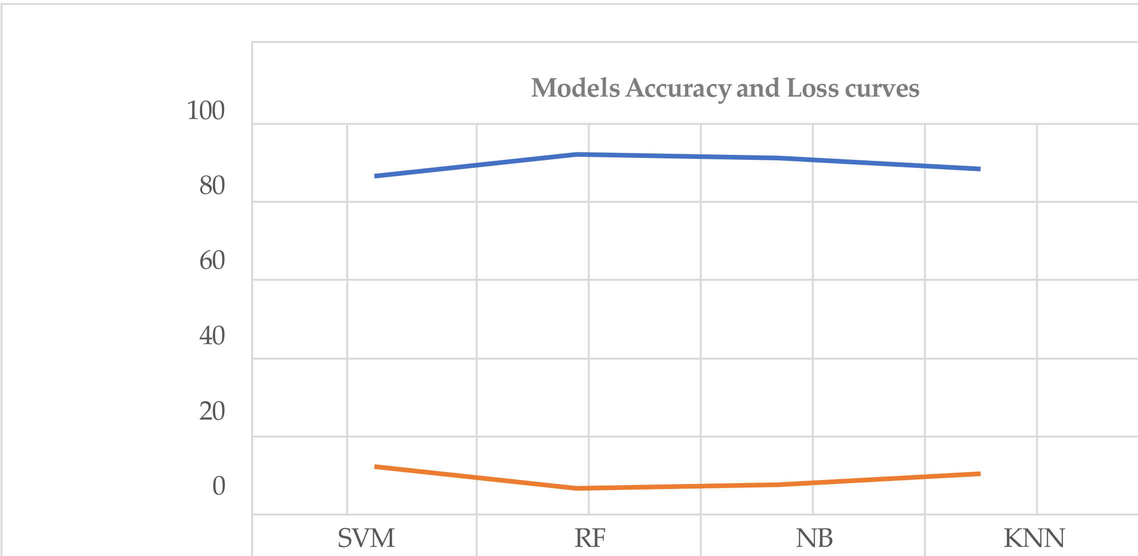
An agricultural production system that is climate-smart analyses soil and climate data. Preprocessing methods are used to clean up and change the data before splitting it into testing and training sets. Soft computing models analyze the data to draw inferences and forecasts.

2.3.2. To Enhance Crop Yield Using Soft Computing

These models could be used to optimize crop selection based on the current environmental conditions. This research examines the application of four common soft computing models—Support Vector Machines (SVM), Random Forest, Naive Bayes, and K-Nearest Neighbors (KNN)—in crop recommendation systems. Hyperplanes are used by the efficient classification technique SVM to partition data points into groups with the maximum margin. Based on a variety of input criteria, it has been frequently utilized in agriculture to forecast crop suitability. In contrast, KNN is a non-parametric algorithm that groups new instances according to how close they are to their k-nearest neighbors. When there is no explicit mathematical model to explain the link between the input and output variables, it is especially helpful. A probabilistic technique called Naive Bayes determines the conditional probability of a given class given the input parameters and assumes that features are independent. It is renowned for being straightforward, quick, and capable of handling big datasets one of the effective classification methods in data analysis and machine learning is naive Bayes. Despite being effective, naive Bayes learners struggle with the faulty assumption that there is a conditional relationship between the qualities [18]. The last ensemble learning technique is called Random Forest, which blends various decision trees to provide predictions. In order to highlight the data, ensembles adopt a different strategy than a single classifier. This involves building multiple ensembles and combining all of the individual students depending on a voting process [17]. Prediction models are made using the random forest classification machine learning approach. Reducing the number of variables needed to produce a forecast is often a goal in prediction modeling to lower data collection costs and increase efficacy [15]. It generates precise findings by accounting for a wide range of variables and their interactions, making it resistant to overfitting. The purpose of this thesis is to develop a system for crop suggestion that considers climatic factors like humidity, rainfall, and temperature in addition to soil parameters like pH and NPK levels. By using the power of computational models such as SVM, KNN, Naive Bayesian, and Random Forest, we have created a dependable and precise system that can assist farmers in selecting the optimal crop.

3. Results

Figure 4 shows the accuracy and loss curves graph for four supervised classification algorithms—RF, KNN, SVM, and Naive Bayes—that have been used in this work to compare soil and meteorological factors and select the best crop based on soil attributes and season.



	SVM	RF	NB	KNN
Accuracy	90	96	95	92
Loss	10	4	5	8

Figure 4. Model Accuracy Curve

The system plan of action consists of three phases. It begins by gathering and preprocessing relevant data, including details on the pH, nutrient content, texture, and weather (temperature, humidity, and rainfall). Next, the system uses soft computing techniques to assess the data and generate suggestions. In order to train a dataset of soil properties for crop recommendation, the machine learning models k-nearest neighbor (KNN), random forest, naive Bayes, and support vector machine (SVM) were utilized. SVM is an effective supervised learning method that may be applied to regression and classification problems. SVM may be used in the crop suggestion scenario to categorize the crop type according to the characteristics of the soil. There is a tight link between classic perceptron-based neural networks and support vector machine (SVM) models. [14]. It builds a hyperplane to optimally divide various crop classes. The support vector machine (SVM) method is utilized in many different disciplines because it is a trustworthy, efficient classification tool in the field of machine learning [16]. Using the kernel functions, SVM can handle both linear and non-linear connections, making it useful for handling high-dimensional data. Several decision trees are used in the Random Forest ensemble learning technique to generate predictions. It generates the average or mean forecast of each decision tree after building a large number of them. Random Forest can capture non-linear correlations, handles high-dimensional data effectively, and is resistant to overfitting. By taking into account several decision trees, it may be used to categorize crops according to soil characteristics. Accuracy and loss comparison of models is shown in Figure 5.

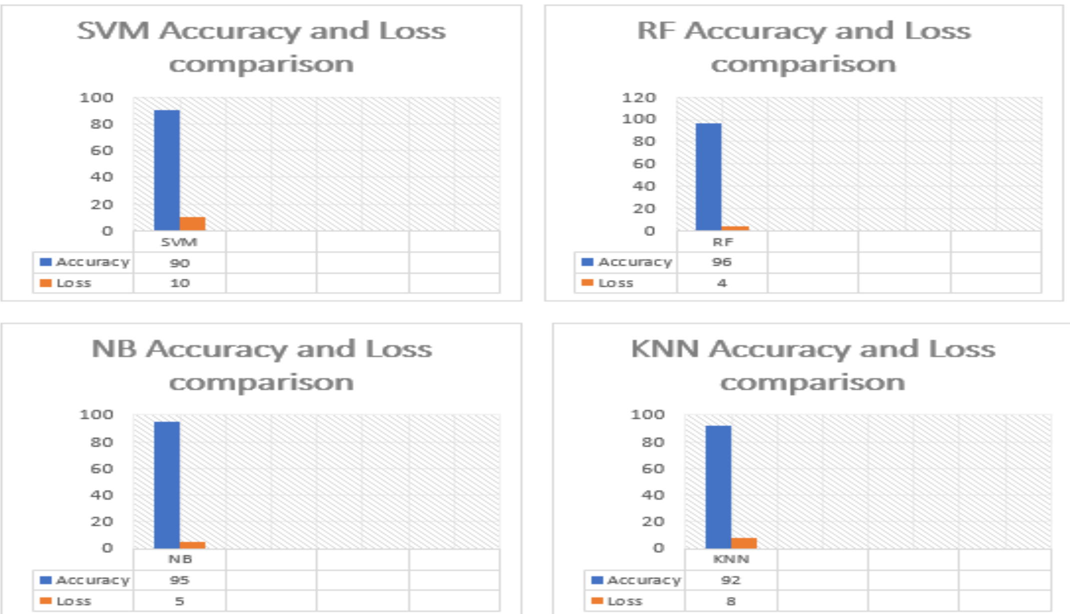


Figure 5. Accuracy and loss comparison of models

4. Discussion

This study's crop recommendation system provides farmers with a clever way to assist them in selecting crops based on soil and meteorological data. By utilizing soft computing techniques, the system boosts agricultural productivity, lowers the likelihood of crop failure, and encourages sustainable farming practices. This research advances precision agriculture by maximizing crop output via artificial intelligence and data- driven decision-making. Achieving food security and sustainable development requires the agriculture sector. It can be challenging to choose the best crop to plant in a given location depending on soil and climate conditions. To solve this problem, a soft computing-based crop recommendation system has been developed. The goal of this research endeavor is to deploy a dependable crop recommendation system that utilizes soft computing techniques in order to enhance crop selection and increase agricultural production. With the use of this technology, farmers may make educated decisions on crop cultivation by accounting for local soil and climatic conditions. The proposed system makes use of advanced soft computing techniques including fuzzy logic, neural networks, and evolutionary algorithms. A more flexible decision-making process is made possible by the application of fuzzy logic to handle uncertainty in soil and meteorological data. Through the evaluation of several factors and the determination of the optimal combination depending on the available inputs, genetic algorithms enhance crop selection. Neural networks are utilized to train the algorithm and provide accurate crop production projections with the use of historical data.

References

1. Gupta, K., Senger, N., Bahl, V., & Goel, A. (2022). Agricultural Production Optimization.
2. Koley, S. (2014). Machine learning for soil fertility and plant nutrient management using back propagation neural networks. Shivnath Ghosh, Santanu Koley (2014)"Machine Learning for Soil Fertility and Plant Nutrient Management using Back Propagation Neural Networks" International Journal on Recent and Innovation Trends in Computing and Communication, 2(2), 292-297..
3. Malhi, G., M. Kaur, P.K.- Sustainability and U. 2021. 2021. Impact of climate change on agriculture and its mitigation strategies: A review. Mdpi.Com.
4. Gandhi, N., … O.P.-2016 I.T. and U. 2016. 2016. Rice crop yield prediction using artificial neural networks. In: Ieeexplore.Ieee.Org.
5. Hussain, M., A.R. Butt, F. Uzma, R. Ahmed, S. Irshad, A. Rehman and B. Yousaf. 2020. A comprehensive review of climate change impacts, adaptation, and mitigation on environmental and natural calamities in Pakistan. Environ. Monit. Assess. 192.
6. Kumar, A., O.R. Pooniwala and S. Chakraborty. 2020. " Intelligent Crop Recommendation System using ML ."
7. Modi, D., A. Sutagundar, … V.Y.-… S. and and U. 2021. 2021. Crop Recommendation Using Machine Learning Algorithm. In: Ieeexplore.Ieee.Org.
8. Masri, D., W.L. Woon and Z. Aung. 2015. Soil property prediction: An extreme learning machine approach. Lect. Notes Comput. Sci. (Including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics). 9490:18–27.
9. Gosai, D., C. Raval, R. Nayak, … H.J.-I.J. of and U. 2021. 2021. Crop recommendation system using machine learning.
10. Academia.Edu. 7: 554-557.
11. Chandio, A., Y. Jiang, A. Rauf, F. Ahmad, W.A.- Sustainability and U. 2020. 2020a. Assessment of formal credit and climate change impact on agricultural production in Pakistan: a time series ARDL modeling approach. Mdpi.Com. 12.
12. Charbuty, B. and A. Abdulazeez. 2021. Classification Based on Decision Tree Algorithm for Machine Learning. J. Appl. Sci. Technol. Trends. 2:20–28.
13. Ginbo, T. 2022. Heterogeneous impacts of climate change on crop yields across altitudes in Ethiopia. Clim. Change. 170.
14. Harinditha Ruchirawya, T., P. Bandara, S. Lanka Thilini Weerasooriya Assistant Lecturer, S.T. Lanka Ruchirawya, W. Nanayakkara, S. Lanka Dimantha MAC and P. Mgp. 2020. Crop recommendation system. Researchgate.Net. 175:975–8887.
15. Osisanwo, F., J. Akinsola, … O.A.-… J. of C. and undefined 2017. 2017. Supervised machine learning algorithms: classification and comparison. Researchgate.Net. 48.
16. Speiser, J.L., M.E. Miller, J. Tooze and E. Ip. 2019. A comparison of random forest variable selection methods for classification prediction modeling. Expert Syst. Appl. 134:93–101.
17. Abdullah, D.M. and A.M. Abdulazeez. 2021. Machine Learning Applications based on SVM Classification : A Review. Qubahan Acad. J. 1:81–90.
18. Shaik, A.B. and S. Srinivasan. 2019. A brief survey on random forest ensembles in classification model. In: Lecture Notes in Networks and Systems, Springer, 253–260.
19. Taheri, A.H.J.M. 2017. The 19th CSI International Symposium on Artificial Intelligence and Signal Processing (AISP) : Shiraz University, Shiraz, Iran. 134–139.