International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 23 (2017) pp. 13966-13973

A Machine Learning Approach to Assess Crop Specific Suitability for Small/Marginal Scale Croplands

Ratnmala Bhimanpallewar
PhD Scholar, Computer Science and Engineering Department, K L University, Green Fields, Vaddeswaram, Guntur District, Andhra Pradesh, Pincode- 522502, India.
Orcid Id: 0000-0001-8098-9776

M. R. Narasinagrao
Professor, Computer Science and Engineering Department, K L University, Green Fields, Vaddeswaram, Guntur District, Andhra Pradesh, Pincode 522502, India.
Orcid Id: 0000-0002-1484-1551

Abstract

Agriculture is a backbone of Indian economy. It is very important to increase the crop yield to satisfy the need of increasing population. Most of the Indian farmers hold fragmented cropland and their yield is dependent on availability of various factors like soil-quality, rainfall and environmental condition etc. Average annual soil loss in India is about 5.3 billion tonnes. Degraded land loses capacity to produce adequate yield for few crops but same land can give good production for some other crops. To adopt such suitable crop proposed system focuses on evaluation of crop-specific current and potential soil suitability.

Keywords: Soil suitability, Fragmented land, Soil nutrients, Decision tree.

Abbreviations: FAO (Food And Agriculture Organization), GOI (Government Of India), KVK (Ksishi Vigyan Kendra).

INTRODUCTION

Some small scale Indian farmers are becoming cautious about their crop production. They approach to nearby KVK center (The term used in India , Maharashtra state for office where farmers can get their soil samples tested to know available soil nutrients and their proportion) to get the report of their soil testing, but the information they get out of it couldn't help them directly to decide which crop has to be adopted to gain maximum crop yield. Proposed methodology is based on machine learning technique where input parameters are existing availability of components in soil, environmental parameters along with selected crop and output is suitability level for respective crop. Many farmers have habit to take crops continuously without understanding capability of land. This system will help to take decisions like how to improve soil suitability or to keep the land free for some duration as its not capable. The report "India Country Programming Framework, 2016" by FAO [1] says that land degradation constitutes a major threat to India's food and environmental security. So increasing the crop yield plays important role in satisfying the food requirements for increasing population of human beings and live stocks too. Average annual soil loss in India is about 5.3 billion tonnes.

ALSE(Agriculture Land Suitability Evaluator) is one of the recent land suitability evaluator[2]. It is a tool for decision making, helps to compute suitability of crops like mango, banana, papaya, citrus, and guava also plan the crops as per suitability levels. Input parameters are 1.local and worldwide cultivation knowledge 2.cultivation history 3.experimental land characteristics and 4.optimal requirements for considered crop. Another is Climate module where input parameters are 1.data of annual precipitation (mm) 2.length of the dry season per month and 3.topography effect measured by slope in degrees. In case of soil module inputs taken are 1.soil workability 2.nutrient retention 3.availability of nutrient, rooting condition and 4.oxygen soil drainage class. The system is developed using very basic language i.e. Visual Basic which cannot support efficient programming and web features. Also it is not for major crops and fragmented land.

The Micro-LEIS[3] performed Agro-ecological land evaluation by Rosa et al. in 1992 and revised in 2009. Input parameters are 1. place (climate) 2. land (climate, site, soil) 3. soil (site-soil) and 4. field (climate, site, soil, management) data and knowledge of engineering through use of a variety of Geo-referenced Databases, Computer Programs, Boolean, Statistical, Embedded System and Neural Network modeling Techniques. This is designed once and standardized, user don't have flexibility to build own expert system using it. So users can't view the results as per their current requirements.

LEIGIS[4] is a software application developed by Kalogirou (2002) it worked like crop planner for rural farmers for specified crops. It is designed to support rural planners with the first view of the land suitability for cultivation of certain crops like wheat, barley, maize, seed cotton, and sugar beet. It doesn't consider any environmental property whereas environment plays a key role in crop production.

LIMEX is the system with multimedia capabilities[5]. It is integrated with text, image, sound, video and data which made the system interactive and more flexible. So it takes inputs as digital maps, geographical database and output is in terms of maps. It basically focuses on assessment, irrigation, utility of fertilizers, and pest control not the crop suitability. Drawback of the system is it does not support wide range of problems in land evaluation.

All above automated systems are used in different countries for large scale crop lands, none of it is applicable for marginal or small fragmented farming in India[6]. While talking about national context [1] FAO says that in India among the population of 1.25 billion people, over 70 per cent of rural Indian households including livestock are totally dependent on agriculture. Indian agriculture is mainly a combination of marginal and small scale farmers. The gradual decline in size of farm holdings has made a large proportion of small and marginal farms to look for livelihood opportunities other than in agriculture.

All the successful automated systems regarding agriculture fields are built by assuming an adequate water supply where as 62 per cent of Indian farm lands are rain-fed. After collaboration with FAO gradually country has moved on food aid to become a net food exporter. But the share of agriculture in total GDP is projected to further go down from 18 per cent in 2013-14 to 7-8 per cent by 2019-20. Country has achieved self-sufficiency in food production but new challenges have been emerged. In last three years agricultural growth rate has reduced to 1.7 per cent, so major threat caused by land degradation to India's food and environmental security. Large fields of farmlands in India have become barren[1] due to imbalanced use of fertilizers and excessive use of a fertilizer such as urea. Urea is cheap form of Nitrogen.

Soil degradation is nothing but decrease in the soil quality. It is observed due to continuous use of wrong practices by farmers [7]. To overcome those problems one of the priority set by GOI along with FAO (UNDAF 2013-2017) is for the sustainable development of agriculture focusing primarily on managing natural resources which are under threat by: (i) apply approaches and tools that have been pioneered by FAO in India to restore degraded lands, and (ii) soil and ground water management.

Along with the efforts taken by State and Central Government 'Agriculture Universities also arrange sessions and Exhibitions on different Agriculture modern tools and practices but all the farmers cannot take the advantage. Although all these facilities are available, it doesn't help farmers whenever and from wherever they want to access.

Economic survey till 2012-13 gives details about yield per hector of major crops in India and state-wise[8][9]. Observing that this system is developed for major crops like jowar, wheat and rice. FAO guidelines are available for land evaluation . Proposed system is using the guidelines from FAO Land Evaluation Framework published in 1976[10], 1983[11], Guidelines: Land evaluation for rainfed agriculture, FAO Soils Bulletin 52 ,55(1985), 58(1991), 67(1993), 73(1996) for different objectives[12][13][14][15]. Referring all these we have chosen the system parameters.

MATERIAL AND METHODS

Traditional practice of Rural farmers is as below:

They choose the crop/crops, proceed with it at the beginning of season.

Add the fertilizers for that specific crop/crops as per their traditional way.

Definitely choosing the crop/crops, fertilizes and proportion of fertilizers is decided by experience and through the discussions with local expert farmers. This habit is giving them benefit since long ago. But it is raising new problems like land degradation due to excess quantity of fertilizers. The objective of this system is to improve the regular method by suggesting few modifications as fallowing:

Farmer has to collect their soil samples to nearby KVK center to know the proportions of the existing soil components- as a standard practice it should be done once in two years.

I. Depending on the availability of existing environmental condition and soil components, identify suitable crop from this model rather 'crop specific suitability' and choose the crop/crops accordingly.

II. To increase the yield add appropriate fertilizers in adequate proportion suggested by decision support system.

This paper has focus on only step I i. e. Computing crop specific suitability

To increase the yield add appropriate fertilizers in adequate proportion suggested by decision support system.

This paper has more focus on modification i. Computing crop specific suitability.

Module Details

It is a software module developed for few major crops in India like wheat, rice and jowar [16] [17]. Basic soil and environmental parameters need to consider for every specific crop. Those parameters are taken input from two users.

It is a hybrid Machine learning model used to take decision whether a specific crop is to be cultivated or not on the basis of suitability of existing land properties and environmental properties. Real time dataset is collected from Agriculture University since year 2009-10 till 2013-14. Accurate training data set allows us to use machine learning technique which will generate more practical decision. Database stored using SQL and algorithm implemented using JAVA language.

Algorithm: A Hybrid Machine Learning Model

Important Terminologies:-

Information gain (G):

Information gain is nothing but the difference between the information needed to identify an element of T(mostly class element) and the information needed to identify an element of T after the value of attribute X (mostly non-class element) has been obtained.

Probability Distribution(P):

Probability distribution of the parameter P (input or output parameter) is computing the probability of the occurrence of every instance value Pi in the set of all n instances. where parameter P takes values P={P1, P2,..., Pn}.

It is a hybrid machine learning model used to evaluate suitability levels. Most of the logic is based on decision tree algorithm which allows us to generate multiple outcomes[18] [19] [20]. Here we are generating five outcomes i.e. s1, s2, s3, N1 and N2. Suitability levels are evaluated as current and potential suitability in two separate iterations.

Steps for Algorithms:

I. Divide the dataset into two parts training dataset and testing dataset.

Here output vector is nothing but suitability levels for the cropland,

T={ T1, T2, T3, T4,T5}

i.e. Suitability Level={ S1, S2, S3, N1, N2}

1. X- set of every parameter considered as input i.e. {X1,X2,..., Xn}where, n- number of input parameters
   T- output/class parameter
2. Select one parameter output(T) or input(Xi) consider it as P

Calculate the probability distribution of that parameter

2.1 Parameter may takes categorical values [Ex. parameter Soil Topography which takes value {1(Plain), 2(Gentle slope), 3(Deep slop)}]

2.2 Parameter takes continuous values, then split it depending on the probability of the range of parameter values occurred under the particular class value Ti, parameter values will be partitioned into categories using ranges.[Ex. In Fig 1. probability distribution of parameter Rainfall is as, p1(Rainfall<=38), p2(Rainfall>38)].

P=(p1,p2,p3.....pn)

3. Calculate the Entropy of P as:

I(P) = -(p1*log(p1) + p2*log(p2) + .. + pn*log(pn))

[More the uniformity in the probability distribution, the greater it gives information.]

4. T- set of records which are partitioned on the basis of class values C1, C2, .., Ck

when, P- is the probability distribution of the partition (C1, C2, .., Ck)

then the information needed to identify the class of an element of T is

Info(T) = I(P)

P = (|C1|/|T|, |C2|/|T|, ..., |Ck|/|T|)

5. After partitioning on the basis of class value into sets T1, T2,...,Tn

The information needed to identify the class of an element of T= the weighted average of the information needed to identify the class of an element of Ti, i.e. the weighted average of Info(Ti):

$$\text{Info}(Xi,T) = \text{Sum for i from 1 to n of } \frac{|Ti|}{|T|} * \text{Info}(Ti)$$

6. Information Gain of parameter Xi is:

Gain(Xi,T) = Info(T) - Info(Xi,T)

7. Repeat the procedure 2 to 6 for all the parameters to get the vector

G={Gain(X1,T), Gain(X2,T),....., Gain(Xn, T)}

8. Choose the parameter Xi such that Gain(Xi,T) is higher than the other parameters considered. Identify the sub-braches under that node as, If the probability distribution of the parameter Xi i.e. P is (for first iteration it will be root node) Refer Step.2

P=(p1,p2,p3.....pn)

Then,

p1- subset of the dataset belongs to sub -branch 1

p2- subset of the dataset belongs to sub -branch 2

.

.

pn- subset of the dataset belongs to sub -branch n

9. Choose one of the sub-branch and respective subset of the dataset .

Repeat the procedure 1-9 till last sub-branch will be the class node/leaf node.

10. Prune the tree if required (Logically not graphically).

11. Once the logical tree is ready verify this for the testing dataset.

Error rate allowed is- Variation allowed in output: +1 level or -1 level.

If error generated > ± 1 then, repeat the procedure 1 to 11 for the sub-branch which is identified as misclassified.

II. Model is trained using training dataset and verified using testing dataset

Now compare the suitability outcome of the decision tree approach with raster scan system.

a. If it is giving correct output with allowed error rate then display current suitability and expected improvements for potential suitability.
b. Else generate the outcome suitability using raster scan system and display it. In this case the conclusion is dataset selected is not appropriate, so we need to train the whole model again with another appropriate dataset.

RESULTS

Input and Output Parameters

Input Parameters

Few Vital parameters are considered as here are rainfall, temperature, moisture, soil type, topography, pH(alkalinity) and soil nutrients NPK (Nitrogen, Phosphorous, and Potash(Potassium)[17] .

Ranges of the parameter Table 1 are referred from the reports published by agriculture university [17] and FAO [21] [22]. It is valid for soil type in Pune region Maharashtra, India. This case study is for small scale or marginal farmers, holding fragmented land.

In India cropping season is classified into two main seasons- (i) Kharif and (ii) Rabbi. Jowar is a tropical crop. Case study discussed here is about sorghum (jowar). In kharif season its water supply is dependent on rainfall, where as in rabbi season it depends on water holding capacity of land, natural reservoirs like canals, ground water whales, small lakes (now a day's farmers are preparing it in farmland itself before rainy season and store water from rainfall), surface water tanks etc. Assumption is that these water sources are sufficient for required water supply and those are indirectly dependent on rainfall, so one of the input parameter is precipitation. Table 1 indicates the valid input ranges and Table 2 indicates the favorable parameter ranges for increasing yield of Jowar[23], [17] [21] [24] [25] [26].

Table 1: Input ranges

Values	Range
Temperature	1 to 100
Average Rainfall	10 to 500
Type of soil	1 to 4
Moisture of soil	10 to 200
Topography	1 to 3
PH Value	1.0 to 10
EC Value	1.0 to 10.0
N Value	1 to 500
K Value	1 to 500
P Value	1 to 500

Table 2. Suitable ranges for Jowar

Values	Range
Temperature	25° and 45°C
Average Rainfall	30 and 65 cm
Type of soil	1- 3
Moisture of soil	30cm to 100 cm
Topography	1- 2
PH Value	5.5 – 7.5
EC Value	1.0 to 6.0
N Value	100 Kg/Hect
K Value	50 Kg/Hect
P Value	50 Kg/Hect

Here suitability for crop Jowar is predicted on the basis of above 10 parameters. Depending on the soil type available, land in India had been categorized into twenty different agro-ecological zones [16]. After observing area under major crops, for simplicity we categorized whole cropland of India into four categories 1- black clayey loams, 2- heavy and light alluvium to red, 3- grey and yellow loams and 4- sandy soils. Out of these four types sandy soil is not suitable for jowar, so not indicated in Table 2. Soil type in Pune, Maharashtra categorized as a combination of saline, sodic soils (Solonchaks, Solonetz) and red soils (Acrisols). Topography of the land categorized as 1- plain, 2- gentle slope and 3- deep slope. Most of the land in Pune region comes under either plain or gentle sloping. Table 2 is referred to prepare raster scan system, it is a kind of matrix to verify the predicted suitability outcome with respect to expert knowledge.

Output Parameters

Soil suitability levels are categorized into five levels depending on their qualitative and quantitative features [27] [28]. The ranges of classification are:

s1- Suitable

s2- Moderately suitable

s3- Marginally suitable

N1- Not suitable (due to major economic reasons otherwise moderately suitable)

N2- Not suitable (due to physical reasons).

Provided that we can further compute current and potential suitability with assumption that soil quality can be improved by some extent with addition of essential soil components externally.

Dataset Description

Case study for Jowar for computing suitability S is considered. Sample dataset is as below:

Table 3. Sample Dataset for Jowar crop

Crop	Temp	Rai-n fall	Soi-l Type	Soil Moisture	Top	pH	EC	N	P	K	S
J	28	0	1	60	1	5	2	56	46	48	28
J	28	0	1	60	1	5	2	56	45	48	28
J	29	30	1	65	1	5	2.1	56	37	45	29
J	27	30	1	67	1	6	2.1	67	50	45	27
J	27	45	1	67	1	6	2.1	67	47	45	27
J	29	35	1	67	1	6	2.1	67	46	46	29
J	29	35	1	67	1	6	2.1	67	47	46	29
J	33	36	1	67	1	5	2.1	78	47	44	33
J	32	38	1	67	1	5	2.1	67	47	47	32
J	30	45	1	70	1	5	2.1	77	48	47	30
J	30	30	1	60	1	5	2.1	56	45	48	30
J	30	0	1	68	1	6	2	56	45	48	30
J	26	0	1	56	1	6	2	56	45	48	26
J	28	0	1	60	1	5	2	56	46	48	28

Fourteen samples are collected from one farmland Table 3. Here abbreviations used are J- Jowar, Top- topography and Temp- temperature. Average values are considered while monitoring few parameters example rainfall- average rainfall of the kharif season is considered here. Organic factors are measured at KRISHI VIGYAN KENDRA by taking random samples from farmland.

Detailed region wise aggregate reports are maintained at KRISHI BHAVAN, either seasonally or annually. One sample report is as below for year 2009-10.

Table 4. Sample Aggregate Report Year 2009-10 for EC

Ksharata (Electrical Conductivity) No. of Samples in given Range					
Sr No.	<1	1 to 2	2.01 to 3	>3.01	Total
1	24	26	28	30	32
2	0	0	0	0	0
3	1053	20	3	7	1083
4	1425	3	0	1	1429
5	427	3	0	0	430
6	739	0	0	0	739
7	62	2	1	0	65
8	2771	40	16	2	2837
9	1421	22	1	4	1448
10	926	6	2	5	939
11	492	18	3	7	520
12	1398	2	0	1	1401
13	840	28	2	3	873
14	982	29	12	19	1042
15	794	5	1	2	802
Total	92	26	5	2	125

Similar to aggregate EC records are maintained in Table 4, records for pH and NPK values also avialabble. Some environmental parameters are collected from reports published by India Meteorological Department, Pune for the respective duration. Whole data collected is real time. This is the observation of total 13733 tested samples. Dataset is generated using this aggregate reports. Work is done at Vishwakarma Institute of Information Technology, Pune-411048.

Results for real-time dataset

Complete SQL database is prepared similar to Table 3 from all historical database available, like in Table 4 for EC measure. It is divided into training and testing dataset and fed as input to above algorithm. While computing potential suitability, few input parameter values are suggested to modify. Practically that modification is asked to cover by adding appropriate fertilizers.

Results:

1. There are three categories of input factors depending on the ranges of information gain. Factors with

   High information gain: rainfall, soil-type, topography and temperature.

   Moderate information gain: soil moisture, EC and pH,

   Average information gain: N, P, and K.

   A node with highest information gain is Topography

2. Instances categorized as below:

   Correctly Classified Instances 73938

   Incorrectly Classified Instances 799

Suitability levels compared with fertility index [29]. Results are aligned.

Advantages:

1. Results are improved after implementing the model on real-time hybrid dataset.

   Accuracy=98.9%

   Error rate= 1.10%

2. Considered all types of input attributes.
3. Tree pruned .
4. After evaluating performance of above model error rate observed are

Mean absolute error	0.0072
Root mean squared error	0.0601

Actual output generated by this system is in terms of current suitability level and expected improvements required to achieve potential suitability level. If the lagging parameters are the parameters which can be modified artificially and we can achieve the target of expected value shown in Fig. 2 then, potential suitability level = ++ current suitability level. Output for the sample case is shown below:

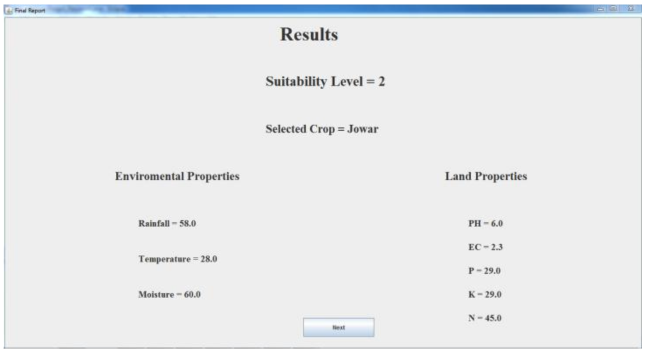

Figure 1: Soil suitability by Hybrid Machine Learning model

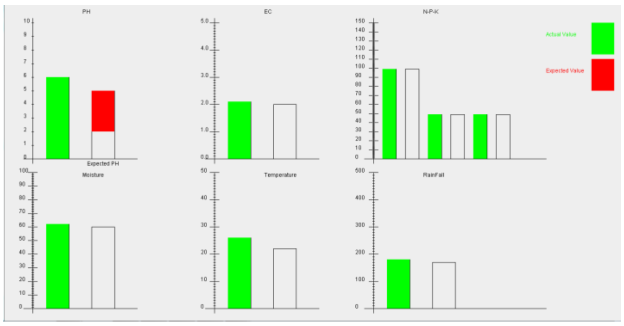

Figure 2: Graphical representation of expected parameters.

In Fig. 1 if the input value is not as expected then the expected value will be indicated in red color side bar as shown in Fig. 2.

DISCUSSION

This hybrid approach is based on c4.5 tree algorithm, so all types of attributes can fed as inputs. It performs proper categorization of continuous attributes also. Here classification rules generated are aligned with pruned tree. Always pruned tree is smaller and more accurate. The main advantage is that, it can generate rules from a single tree and transforms multiple decision trees for the same task into a set of rules [30]. While generating classification rules it can deal with the training set with unknown values of attributes also. It compute those unknown values by estimating the probability of the various possible results. One drawback of this rules creation is that, creates only a subset of all possible rules which can be created from the corresponding raw tree. This may lead to a problem that, it doesn't work appropriately for few worst cases. To handle such worst cases raster scan system is also provided here. So all together this hybrid model can be fitted for all kinds of instances.

This dynamic model gives us a privilege to fit the model to real-time scenario by choosing real-time dataset. Obviously the model trained in such a way will give practicable decisions. So users can view the results as per their current requirements.

Developed System is user friendly and simple for understanding. So small scale farmers can use it as a guide for deciding the crop to be cultivated. It will contribute in increasing yield without degrading soil quality.

FUTURE WORK

This system be extended for other crops. Sensitivity analysis can be improved by using more precise methods. It can also be extended to suggest the appropriate fertilizers and its approximate quantity, as the results are aligned with it.

ACKNOWLEDGEMENT

The authors are grateful to the Krishi Vidyapeeth and Meteorological Department at Pune for providing real-time dataset indirectly through publically available reports.

REFERENCES

[1] "India Country Programming Framework," 2016.

[2] R. Elsheikh, A. R. B. Mohamed Shariff, F. Amiri, N. B. Ahmad, S. K. Balasundram, and M. A. M. Soom, "Agriculture Land Suitability Evaluator (ALSE): A decision and planning support tool for tropical and subtropical crops," *Comput. Electron. Agric.*, vol. 93, pp. 98–110, Apr. 2013.

[3] D. De La Rosa, F. Mayol, E. Diaz-Pereira, M. Fernandez, and D. De La Rosa, "A land evaluation decision support system (MicroLEIS DSS) for agricultural soil protection: With special reference to the Mediterranean region," *Environ. Model. Softw.*, vol. 19, no. 10, pp. 929–942, 2004.

[4] S. Kalogirou, "Expert systems and GIS: An application of land suitability evaluation," *Comput. Environ. Urban Syst.*, vol. 26, no. 2–3, pp. 89–112, 2002.

[5] S. Kalogirou, "Expert systems and GIS: an application of land suitability evaluation.," in *Computers, Environment and Urban Systems 26*, 2002, p. 89–120.

[6] D. M. R. N. R. N. Bhimanpallewar, "A Survey of Automated Advisory Systems in," *Int. J. Adv. Res. Electr. Electron. Instrum. Eng.*, vol. 4, no. 2, pp. 1022–1030, 2015.

[7] "FAO_Chapter 6 - Causes of land degradation." FAO, United Nation.

[8] C. D. of E. A. Officer9, *Area_and_Production_of_Various_Horticulture_Crops*. 2013.

[9] C. D. of E. A. Officer9, *tab114*. 2013.

[10] FAO, "A framework for land evaluation: soil Bulletin 32," *FAO soils bulletin n.32*. p. viii, 87 , 1976.

[11] F. Cavayas, "Table Des Matières." pp. 5–8, 2012.

[12] FAO, *Guidelines: Land evaluation for irrigated agriculture - FAO Soils Bulletin 55*, vol. 55. 1985.

[13] FAO, "Guidelines: land evaluation for extensive grazing," *Soils Bull. 58. Food Agric. Organ. United Nations, Rome, Italy.*, p. 158, 1991.

[14] "Agro-Ecological Assessments for National Planning in Kenya : Database Structure for District Analysis," vol. 154, no. August, 1996.

[15] FAO (Food and Agriculture Organization of the UnitedNations), "Agro-ecological zoning guidelines. FAO Soils bulletin 73." p. 78, 1996.

[16] FAO, "Fertilizer use by crop in India chapter1," *FAO corporate Document Repository*. 2005.

[17] Agriculture University, "Krishi Darshani 2008," Pune, 2008.

[18] G. Malik and M. Tarique, "On Machine Learning Techniques For Multi-class Classification," vol. 3, no. 2, pp. 6–9, 2014.

[19] X. Wu *et al.*, *Top 10 algorithms in data mining*, vol. 14, no. 1. 2008.

[20] P. Flach, *Data, Machine Learning: The Art and Science of Algorithms that Make Sense of*. 2012.

[21] FAO, "2. Water and soil requirements," 2016. [Online]. Available: http://www.fao.org/docrep/u3160e/u3160e04.htm#TopOfPage.

[22] F. Flat, "World Bank assisted Maharashtra Agricultural Competitiveness Project Marketing Strategy Supplement (MSS) District - Ahmednagar Project Implementation Unit (Agriculture)," pp. 1–109.

[23] FAO (Food and Agriculture Organization of the UnitedNations), "Sorghum bicolor." .

[24] E. Vintrou, D. Ienco, A. Begue, and M. Teisseire, "Data mining, a promising tool for large-area cropland mapping," *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens.*, vol. 6, no. 5, pp. 2132–2138, 2013.

[25] F. Arthapedia and T. Indian, "Cropping seasons of India - Kharif & Rabi," no. August 2015. pp. 2015–2016, 2016.

[26] "Complete information on Jowar (Sorghum Vulgare)."

[27] Food and Agriculture Organization of the United Nations (FAO), "Approaches to Land Classification."

p. 123, 1974.

[28] T. D. Copy, “Chapter 1,” *FAO Corp. Doc. Repos.*, 2001.

[29] STCR Indian Government, “__ Districtwise Fertility Index __.” .

[30] J. R. Quinlan, *C4.5: Programs for Machine Learning*. San Francisco, CA, USA: Morgan Kaufmann Publishers Inc., 1993.