Feature Selection towards Soil Classification in the context of Fertility classes using Machine Learning

Janmejay pant, Pushpa Pant, Ashutosh Bhatt, Himanshu Pant, Nirmal Pandey

Abstract: Soil is recognized as one of the most valuable entity which is responsible for sustaining life on the earth. It is clear that Indian economy is largely dependent on agriculture. In India, for a large section of the population the sole or major source of earnings is agriculture. There are many factors which are responsible in yield production and also affect agriculture. Soil is one of them and plays a crucial role in yield production. Soil nutrients are important aspects that contribute to soil fertility. In this paper we classify soil in the form of fertility index level using machine learning. We induced rule model on training data and apply this model on test data for making predictions for fertility level classes. In this paper we have used Rough Set method to classify the data based on fertility level class and calculate the accuracy of the used classifier.

Keywords: Feature Selection, Fertility Index, Rough Set, Soil nutrients, Reduct, Rule

I. INTRODUCTION

Soil nutrients are a crucial property that contributes to the soil fertility and other environment factors [1]. In agriculture it is important to enhance yield or crop production which is dependent on soil management. Enhancing the yield production depends and is directly affected by soil parameters or nutrients such as pH value, organic matters, electrical conductivity, P, K etc. Agriculture is fully dependent on soil quality. But due to heavy agriculture production the quality of soil may decrease and the nutrients present in soil may lost. In recent years machine learning has been very helpful in studying the elimination of nutrients in soil. Nowadays soil classification and prediction problems are easily handled by Machine Learning techniques [2]. Various Machine Learning techniques were used to predict the soil nutrients, soil type and soil moisture [2], [3]. Soil fertility is affected by many factors like air, water, organic matter and nutrients. Due to some factors, like use of fertilizers, pesticides, insecticides, cultivation etc, and the fertility of soil is regularly decreasing in recent times [4]. In India there is deficiency of primary nutrients in agricultural soil. In this regard it would be better to utilize the different type of land such as saline, alkaline wastelands by analyzing different soil fertility parameters such as fertility index and soil depletion index [4].

II. DATA SET DESCRIPTION

In order to classify soil data based on fertility level, the used data set was collected from one of the soil testing laboratories in Almora district (Uttarakhand). We have used Rosetta tool for generating the rules through which we can further classify our data set and we make prediction for the test data. Based on the soil properties the fertility of soil is defined in three different levels. These are Level 1, Level 2 and Level 3.

We have collected the 53 samples of soil from Almora district (Uttarakhand) by random sampling. The complete data is taken from three different sites corresponding to three different varieties of oak trees growing there, namely Banj oak, Tlonj oak and Kharsu oak. Some samples are distributed and some are undistributed. The primary data was sent to soil testing laboratory for measuring the properties of soil. The data set has 11 independent attributes and 1 is dependent or target attribute which is fertility level. Table 1 describes data collected from each soil sample.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>in cm from sample is collected</td>
</tr>
<tr>
<td>sand</td>
<td>Sand particles in soil, %</td>
</tr>
<tr>
<td>slit</td>
<td>Silt particles in soil, %</td>
</tr>
<tr>
<td>clay</td>
<td>clay particles in soil, %</td>
</tr>
<tr>
<td>moisture</td>
<td>Moisture present in soil, %</td>
</tr>
<tr>
<td>pH</td>
<td>pH value of soil</td>
</tr>
<tr>
<td>C</td>
<td>Organic carbon, %</td>
</tr>
<tr>
<td>N</td>
<td>Nitrogen, %</td>
</tr>
<tr>
<td>OM</td>
<td>Organic Matter, %</td>
</tr>
<tr>
<td>C/N</td>
<td>Carbon and Nitrogen Ratio in soil</td>
</tr>
<tr>
<td>Fertility Level</td>
<td>Dependent class</td>
</tr>
</tbody>
</table>

III. MATERIALS AND METHODS

Machine Learning method is used for classification. For this the following concepts are used:

A. Feature Selection

FS technique [5], [6] is used to obtain a reduced representation of the data set that is smaller in volume in comparison to the original one. The reduced features also maintain the integrity of the original data. Now the feature selection technique is expected to identify most significant soil properties specifying the soil fertility [7].
The feature selection method is implemented to extract the most significant soil property for soil fertility level class. In this paper, we have used one machine learning technique that is Rough Set [5], [7], [8]. Feature Selection has four major steps [7]-
(i) Generation Procedure
(ii) Evaluation Subset
(iii) Stopping Criterion
(iv) Validation Procedure.

![Feature Selection Implementation Diagram](image)

In this paper, after extracting the important features, we have developed an automated system for generating the rules which help in soil classification based on soil fertility.

B. Rough Set Theory

RST [12], [14] is one of the most important mathematical tools to deal with uncertainty which may arise due to granularity in domain of discourse or universe. Rough set is also useful to deal vagueness of data. It is a mathematical framework for analyzing tabular data. There are various basic constructs defined by Z. Pawlak [12], [14]. Some of them are:

Information System (IS)

The Appropriate data which is basically used for research work and is arranged in a tabular format is known as information system (IS) [9]. An information system can be formally defined as: Let A=(A1, A2, A3,…, Ak) be a non-empty finite set of attributes and U={a1,a2,…,ak} be a non-empty finite set of k-tuples, known as the objects. V (A1) denotes the set of values for the attributes A1 [9]. Then information system is defined as an ordered pair I(U, A) such that for all i=1,2,…,k there is a function fi [9], [5]. This means, every object in the set U has an attribute value for every element in the set A. The set U is called the universe of the information system [8], [9], [12]. Thus, we can say that Information System is a data table. Let us assume that I=(U, A, C, D) [5] is a decision table or decision system. Here, U is universe of finite set, A is an attribute of data table I and C and D are subsets of A. C is a conditional subset of A and D is decision attribute. Va is the value of set of a, the elements of U are objects [5], [8], [9], [12].

Indiscernibility Relation

Let I=(U, A) be an information system where U={(a1…ak)} is the non-empty finite set of k tuples known as the object and A={A1,…Ak} is a non-empty finite set of attributes [10],[12]. Let be a subset of attributes [10], [12]. Then the set of P-indiscernible objects is defined as the set of objects having the same set of attribute values [10], [12].

The RST treats data in terms of equivalence classes this means set of objects that are indiscernible with respect to attributes [8], [12].

Reducts

The objects of an information system can be divided into a group of similar types, i.e. equivalence classes [8], [10]. An Indiscernibility relation can do this task. However, the entire set of attributes, A, may not be necessary to preserve the Indiscernibility among the set of indiscernible object [8], [9]. We can say that there may a subset that is sufficient to maintain the classification based on Indiscernibility. A minimal set of attributes required to preserve the Indiscernibility relation among the objects of an information system is called a reduct. Let Say, given an information system a reduct [8], [9], [11] is a minimum group of attributes such that [8], [9].

Decision Rules

After getting reducts, rules may be generated from reducts for classification of the objects. IF-THEN rules [9], [12] are constructed by reading of the values for each attribute in the reduct and associating them with one or more decision classes. The THEN-part will only include one decision class unless the decision class is rough with respect to the attributes in the reduct. Rules are evaluated according to how general they are and how specific they are. How general they are in terms of coverage and how specific they are in terms of accuracy.

C. Fundamental Characteristics of Rough Set Theory [8]

1. This theory doesn’t require any prelude and additional information about data. Other similar theories need the same information as preliminary, for example, statistics needs probability, fuzzy set theory needs grade of membership as prior information. But Rough set theory does not require these types of information as prior.

2. For extracting the hidden patterns, the data rough set provides efficient and intelligent methods, algorithms and tools.

3. By using rough set, we can reduce the original data to find the minimal sets which contain the identical knowledge as in the initial data, i.e. we can reduce the dimension or size of original data without losing the information which is derived by the original data. For this we can use feature selection.

4. It allows calculating the importance of the data.

5. Rough set allows producing the set of decision rules in automatic way.

IV. METHODOLOGY

In this paper, we have tried to describe how Rough Set theory is useful for feature selection of soil data. The whole data, which is stored in tabular form, is split in two parts: one is training set and the other is test set. The division of data set in two parts is useful for classification and prediction. The training set is classified using rough set to find reducts and rules. Once we get rules, we then apply the rules in test data to make some predictions and classify the test data. Researchers are using Rough set theory as a classifier to extract the relevant attributes to achieve the accurate and exact classification results. Feature selection is basically finding the reducts
from data to reduce the volume of the data without losing the information.

In this paper we find the reducts, generate rules and obtain classification results for the soil sample based on fertility levels.

V. EXPERIMENT AND RESULTS

We have used rough set in ROSTTA tool to apply our soil samples of different locations of hilly areas in Almora district in Uttarakhand. As we have already discussed in methodology section, we split the data in training and testing parts. For the data we induced a model that is rule model on one part of the data, i.e., induce rule model on training part. We used the same rule model to classify the objects in remaining data, i.e., used the generated rule model on test part. In this section we describe the data used in our experiments to generate results using Rough Set theory.

As stated above we have collected 53 soil samples from the different location of hilly area in Almora district, Uttarakhand. A snapshot of this data set is in Fig 2. In this data the different sites from where we collected the samples were renamed: Banjoak site renamed as S1, Tlionj oak site renamed as S2 and Kharsu oak site renamed as S3. The above data is split out in two parts with split factor 0.5. This means 50 percent of data will split in training part and rest 50 percent will split into test part.

For feature selection we get 28 reducts followed by their support and length.

Once the data is divided into two parts, we can extract reducts and induce Classification rules on training set by Johnson’s algorithm and standard voting method respectively.

For feature selection we get 28 reducts followed by their support and length.
713 classification rules have been generated. These rules are very important for classifying the test set of our soil data. Based on these rules we can predict the exact fertility level class for the test part objects. In the above Fig 6 the generated rules are sorted in by IF and THEN part of the rule. There are 713 rules that have been generated. The following statistics can be defined for each rule:

- **LHS Support**: the total number of objects in the training set matching the IF part.
- **RHS Support**: Number of objects in the training set matching the IF-part and the THEN-part (LHS and RHS support is the same unless the THEN-part contains several decisions).
- **RHS Accuracy**: RHS support divided by LHS support (Accuracy is 1.0 unless the THEN-part contains several decisions).
- **LHS Coverage**: LHS support divided by the number of objects in the training set.
- **RHS Coverage**: RHS Support divided by the number of objects in the decision class listed in the THEN part of the rule.
- **RHS Stability**: Not applicable for the Johnson algorithm (always 1.0).
- **LHS Length**: Number of attributes in the IF-part of the rule.
- **RHS Length**: Number of decisions in the THEN-part of the rule.

The above rules can be used to classify the objects or tuples of test set. Standard voting is used as classification method. In the present study we predict the fertility index class of test set based on the rules.

The confusion matrix [7], [8], [12] in Fig.7 shows the overall accuracy (i.e. 0.961538), as well as the sensitivity [8], [13] and accuracy for each class. For example, the Level 2 decision class has a sensitivity of 1.0 (i.e. of 23+0+0 = 23 objects actually belonging to Level 2, 23 was correctly classified as Level 2: 23/23 = 1.0) and an accuracy of 0.95 (i.e. of 23+1 = 24 objects predicted to Level 2, 23 were actually belonging to this class: 23/24 = 0.95).

**Fig. 7 Classification Rule**

Through the confusion matrix [7], [8] designed above we can define classifier’s performance in terms of accuracy for the given soil data. In our experiments on soil samples the accuracy of rough set is approx 96% which defines 96 percent of tuples are correctly classify by the classifier in terms of fertility level class that is the target class for the data samples.

**VI. CONCLUSION**

In this paper a feature selection is used towards soil classification in terms of soil fertility level classes using machine learning. The target class fertility level is considered in three different levels based on the soil properties. Rough set theory is applied for classification and prediction results and finally calculated the performance of classifier in terms of accuracy where predicted values and actual values also play an important role to calculate the performance of classifier.

**VII. FUTURE SCOPE**

In current research machine learning is widely used in soil science. We can extend this assignment using other machine learning techniques like ANN, Fuzzy etc. Deep learning is another important tool that can be used for implementing a classification model to predict fertility.

**ACKNOWLEDGMENT**

The first author is thankful to Prof R P Pant, Dept. of Mathematics, DSB Campus, Kumaun University Nainital for his continuous guidance and valuable suggestions.

**REFERENCES**

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