

# Hyperspectral Image Classification of Soils using Soft Computing Techniques

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## Abstract

In geotechnical engineering classification of soils is an important aspect because to provide guidance about soils based on their experimental analysis. The classification of system can be done in various ways because one should not rely on empirical information for solving the problems. These soil types are classified based on their behavioural conditions and based on generalized information provided by the scientists, engineers and resource persons. Classification of soil type by visiting particular location is difficult so remote sensing images are used. The most widely used remote sensing method for classification of soils is hyperspectral image (HSI) technology. To classify HSI different soft computing techniques are applied and compared algorithms with their accuracies to know the best algorithm for classification of soil types.

**Keywords:** Hyperspectral image, soil types, soft computing techniques, soil classification

## 1. INTRODUCTION

One of the most crucial resources is soil. For agricultural purposes, classification of various types of soil and its mapping are vital [1]. Planning, managing landforms, and soil use are all essential components of the region's sustainable growth. The process of local planning and evolution typically includes the inventory of the soils [4] as well as their geographical distribution. For quick soil assessment, remote sensing techniques have made some progress in recent years. These methods cover a lot of space quickly and without causing any damage.

Recently, high spectral resolution data from hyperspectral remote sensing satellites has offered good information for detecting various materials on the earth's surface [8]. Since we can obtain spectrally precise geospatial reflectance data at field and landscape scales, soil categorization and mapping using hyperspectral imaging is a useful tool for focused agriculture for food production [2]. High-resolution maps of soil attributes can be created by fusing soil characteristics with reflectance data generated from airborne imaging, eliminating the errors associated with geographic interpolation of soil categorization.

To enhance prediction capabilities and optimise image analysis processes [3]. An essential step in analysing spectral data is separating the signal from the noise. To create a map of soil reflectance spectra that is spatially representative, geometric and atmospheric corrections must first be made [7]. By averaging nearby pixels and using soft computing techniques like genetic algorithms, regression algorithms, neural network algorithms, and fuzzy logic algorithms, the images can subsequently be spatially smoothed. The optimal algorithm for soil type categorization was then determined by comparing algorithms' accuracy.

## 2. Hyperspectral Image

Since 1980, hyperspectral images are used for mapping, mineral identification, tropical soil classification, and rock type classification [17]. These HSI are made up of camera and spectrograph images that are sent to spacecraft via Hyperion and fixed there for the purpose of monitoring the earth's surface. This hyperion continually records the image using several hundred 256-band spectral bands with a wavelength range of 874–1734. In order to detect items in a hyperspectral image based on their features, spectroscopic methods are used. For identifying different types of soil, spectral resolution is where the HSI technology shines.

## 3. Methodology

For this study on the classification of soil types, the districts of the Chittoor and Tirupati regions were selected. Since each region may only include one or two types of soil, it is impossible to find all the different types of soil with just one hyperspectral picture. Four different hyperspectral image regions were employed in the Chittoor and Tirupati districts. Here to classify soil types different soft computing techniques are applied.

### 3.1 Genetic Algorithm (GA)

Each pixel is grouped into other pixels by distance function based on both local and global already calculated segments as part of the way that GA [16] is used to explore the solution space. The design of a GA for picture segmentation must take into account two fundamental issues: choosing a suitable representation for each probable response creating a weight-based workout plan that is appropriate.

Choosing the best representation for each proposed actions choosing the best representation for each potential.

The genetic system can dynamically adjust the parameters to get the optimal performance. Almost every image segmentation method comprises parameters that are used to influence the segmentation results.

The digital image segmentation can be considered as partitioning the pixel naturally based on function defined as  $F$  and size of  $M \times N$  pixels are described as

$$F = F(I, J), 1 \leq i \leq M, 1 \leq j \leq N, 0 \leq F(i, j) \leq c$$

Where  $C$  represent prototype that can be selected freely,  $F$  represents collection of each pixel value and these pixel values ranges from  $[0, 1]$ . The region subset of  $F$  is denoted by  $S = (S_1, \dots, S_K)$

### 3.2 Regression Algorithm

A statistical technique for binary classification issues is simple regression [9]. This could refer to determining whether or not a specific image belongs to a particular class in the context of image processing. The RGB channel values for each image pixel may be the only components of the feature vector for images [10]. The three-dimensional array of pixel RGB values is flattened into a one-dimensional array of real integers with dimensions  $n_x = n_{\text{height}} \times n_{\text{width}} \times 3$ .

A regression model is named because it calculates  $\hat{y} = \sigma(z)$

$$\sigma(z) = \frac{1}{1 + e^{-z}}$$

the regression function

$$z = w^T x + b$$

for a set of parameters,  $ww$  and  $bb$ .  $ww$  is a  $n \times$  -dimensional vector (one component for each component of the feature vector) and  $b$  is a constant "bias"[11].

### 3.3 Neural Network Algorithm (NN)

Layers are the vertically stacked parts that make up a neural network [5]. The image's dotted lines each signify a layer. A NN has three different kinds of layers.

A neural network is made up of a lot of synthetic neurons that are layered together to form a network of neurons. The following categories of neuronal layers exist:

- Layer of input. Here, input data is provided to the network that has been already converted to the desired format (lists, arrays).
- Layer for output. A layer that transforms input data into output data (arrays of numbers) that meet the task's requirements; convolutional layers.
- Convolutional layers, which carry out various types of "learning" operations of input data passing to the output layer, are used in models of deep neural networks.

The backpropagation algorithm (BP) is employed during the model training process to modify the necessary feature fusion layer parameters at the conclusion of each iteration. The complete connected layer's calculating algorithm is:

$$Y_{out} = f(WX_{in} + b)$$

where  $Y$  represents output of fully connected layer, and  $X$  represents input of the fully connected layer,  $W$  represents weight of training,  $f(\cdot)$  is the activation function.

### 3.4 Fuzzy Logic Algorithm (FL)

Fuzzy logic is a method of processing variables that enables the processing of several potential truth values through a single variable [6]. Fuzzy logic makes an effort to resolve issues using an open, imperfect spectrum of facts and heuristics that enables the production of a variety of exact conclusions. Fuzzy logic is intended to resolve issues by taking into account all pertinent data and selecting the optimal course of action given the input.

To classify each pixel in image to find the soil types. For identifying soil types soil color like white (w), gray (g), red (r), brown (b1), black (b) yellow (y) and blue (b2). The classification of soil colors are difficult in an image to overcome this problem fuzzy logic approach is applied to each pixel for classification.

The fuzzy logic rule is in IF-THEN rules. These rules are applied to each pixel in a hyperspectral image in order to decide whether the pixel represents which type of soil.

The fuzzy logic rules applied to find the type of soil

1. If pixel is b and pixel is b1 THEN the pixel =1
2. If pixel is w and pixel is b1 THEN the pixel =1
3. If pixel is w and pixel is b THEN the pixel =1
4. If pixel is g and pixel is r THEN the pixel = 1

5. If pixel is r and pixel is b THEN the pixel =1
6. If pixel is r and pixel is b1 THEN the pixel =1
7. If pixel is g and pixel is y THEN the pixel =1
8. If pixel is w and pixel is b2 THEN the pixel =0
9. If pixel is g and pixel is b THEN the pixel =1
10. If pixel is y and pixel is r THEN the pixel =1
11. If pixel is w and pixel is g THEN the pixel =0
12. If pixel is g and pixel is b2 THEN the pixel =0
13. If pixel is r and pixel is y THEN the pixel =0
14. If pixel is w and pixel is r THEN the pixel =0

#### 4. Experimental Analysis

Hyperspectral images are collected from Chittoor and Tirupati districts shape files by linking python programming with QGIS. Here in this work four different Landsat images of each district are collected for the classification of different types of soils.

The collected hyperspectral images pre-processed by using techniques like data cleaning, data integration, data transformation and data reduction. Then the images are segmented into cubes by taking region of interest (ROI) which is measured in the form of polygon, circle and rectangle. Next segmented images are trained and the soft computing techniques like Genetic Algorithm, regression algorithm, neural network algorithm, fuzzy logic algorithm are applied for classification.

The soil type classified hyperspectral images of four chittoor district regions are show in figure 1 as figure 1 (a), figure 1 (b), figure 1 (c), figure 1 (d). Here each figure describes the classified areas that are represented in different colors and each color classification represents different area of that region like:

In the figure 1 (a), brown colour represents brown sandy soil, yellow color indicates black sandy soil, black color represents black clay soil, green color represents red sandy soil and sky blue represents gray clay soil.

In the Figure 1 (b) red color represents black soils, yellow color represents red sandy soil, dark green represents trees, light green represents red soils, sky blue color represents red loamy soil, blue represents built-up area.

In the figure 1(c) red color represents red clay soil, dark green represents red sandy soil, light green represents black clay soil, yellow color represents forest area with red soil, blue represents built-up area.

In the Figure 1 (d) shows the classified Chittoor district hyperspectral image and figure describes pink color represents red soil, blue colour indicates water Bodies, green colour represents red sandy soil, sky blue represents grey clay soil and black represents unclassified area.

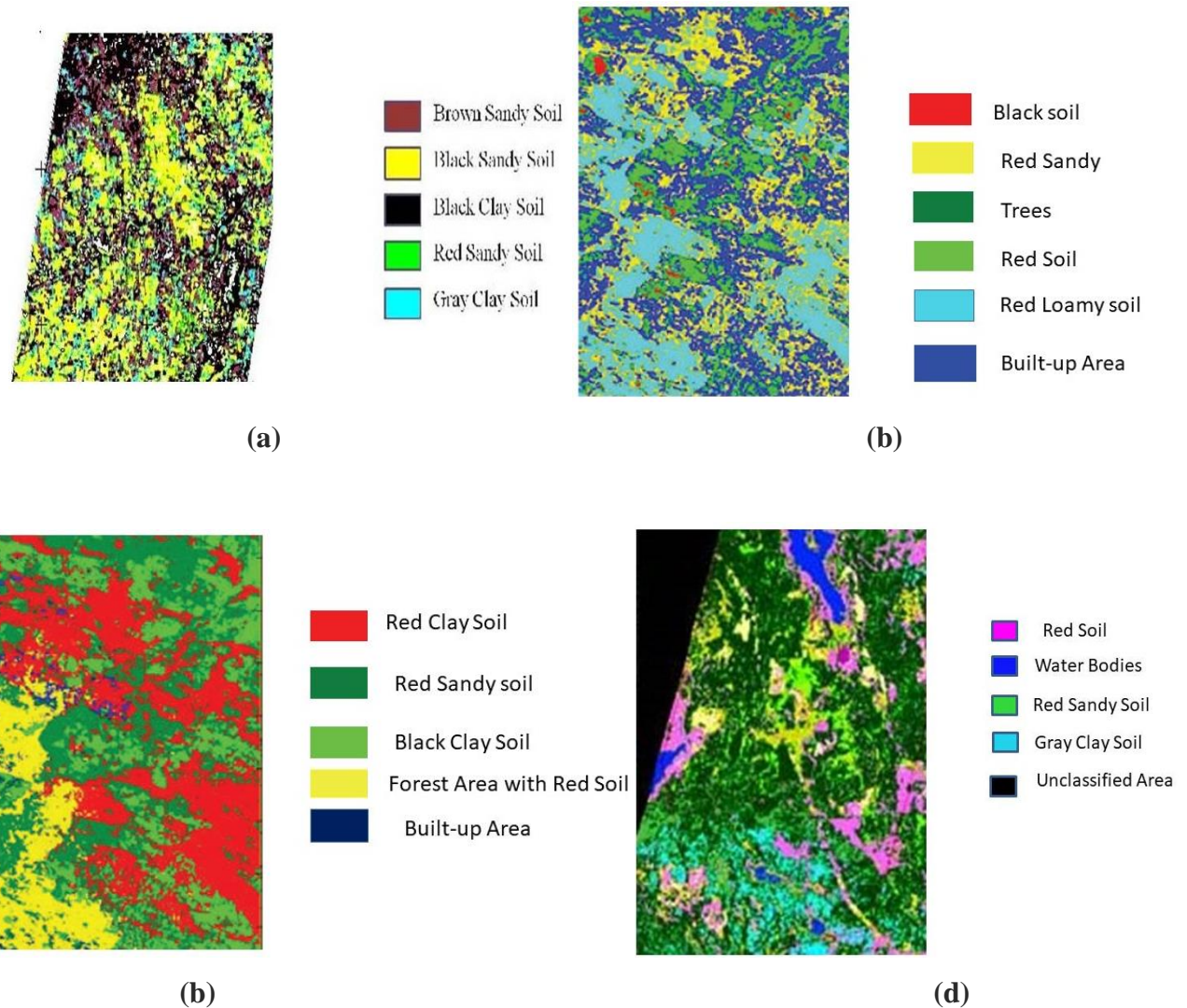


Figure 1: Chittoor District Regions Hyperspectral Image Classification using Soft Computing Techniques

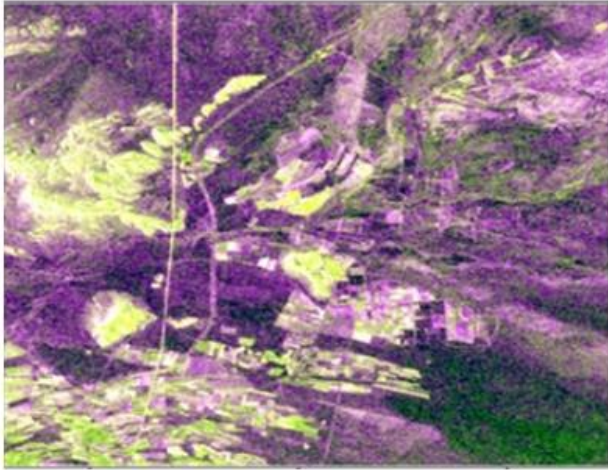
The soil type classified hyperspectral images of four Tirupati district regions are shown in figure 2 as figure 2 (a), figure 2 (b), figure 2 (c), figure 2 (d). Here each figure describes the classified areas that are represented in different colors and each color classification represents different areas of that region like:

In the figure 2 (a) is soil type classified hyperspectral image of Tirupati District regions. Figure 2 (a) yellow color represents built-up area and road, dark green color represents Rock area, light green color represents red soils, violet color represents rock area with trees.

In the figure 2 (b) pink colour represents red soil, blue colour indicates water Bodies, green colour represents red sandy soil and sky blue represents gray clay soil.

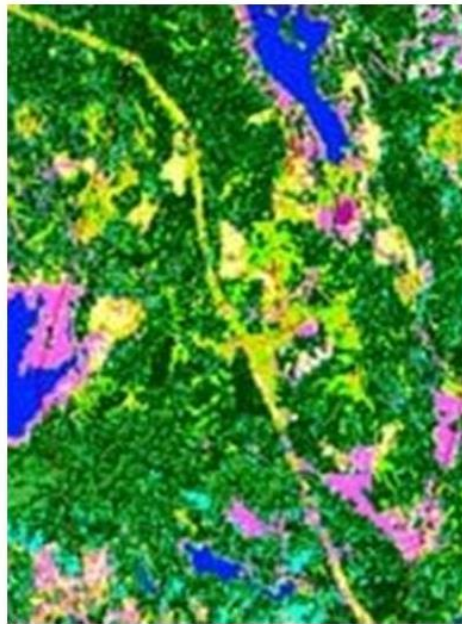
In the figure 2 (c) red color represents red clay soil, yellow color represents forest area with red soil, dark green color represents red sandy soil, light green color represents red loamy soil, blue represents built-up area.

In the figure 2 (d) red color represents red clay soil, dark green color represents red sandy soil, blue represents built-up area, yellow color represents forest area with red soil, light green color represents red loamy soil.



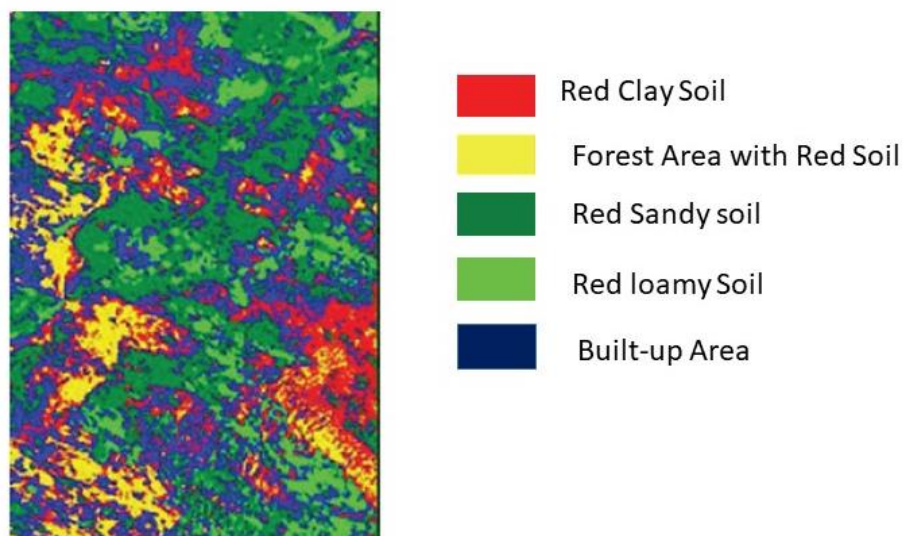
- Build-up area Road
- Rock Area
- Red Soil
- Rock Area with Trees

(a)

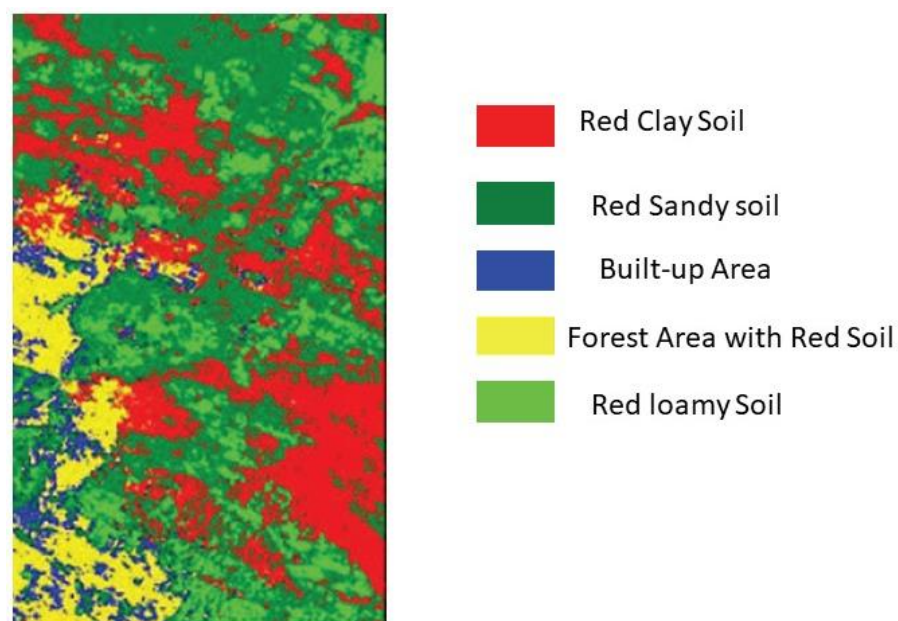


- Red Soil
- Water Bodies
- Red Sandy Soil
- Gray Clay Soil

(b)



(c)



(d)

Figure 2: Tirupati District Regions Hyperspectral Image Classification using Soft Computing Techniques

The classification accuracies of different soft computing techniques are shown in table 1. By observing the accuracies fuzzy logic algorithm is the best algorithm with 97.8% for classification of various types of soils in Chittoor and Tirupati regions soil.

Table 1: Comparison of Soft Computing Techniques accuracies

| S.No | Applied Algorithms   | Accuracies (%) |
|------|----------------------|----------------|
| 1.   | Genetic Algorithm    | 88.92          |
| 2.   | Regression Algorithm | 89.4           |

|           |                          |             |
|-----------|--------------------------|-------------|
| <b>3.</b> | Neural Network Algorithm | <b>92.6</b> |
| <b>4.</b> | Fuzzy logic Algorithm    | <b>97.8</b> |

## 5. Conclusion

Soil is an important habitat for producing green plants and decomposing bacteria and fungi. While air and water are both self-purifying systems with regard to most inorganic contaminants, soil is a sink - receiving fall-out from the atmosphere which it absorbs, filters and could retain materials from infiltrating natural waters. In this context, remote sensing has shown a high potential in soil characteristics retrieving from the last three decades. For the classification of different soil types Maximum Likelihood, K-Nearest Neighbour algorithms and the proposed hybrid algorithm which is a combination of Maximum Likelihood and K-Nearest Neighbour algorithms are applied on HSI images to classify soil types. Then, the experimental results are observed with their accuracies the proposed hybrid algorithm is the best algorithm in classification of soil types with 98.9% accuracy.

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