

Original Research Paper

# Irrigation System Using Hyperspectral Data and Machine Learning Techniques for Smart Agriculture

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**Abstract:** Water is the main resource for agriculture. Management of water in agricultural field is a challenging process. To manage the water content in the agricultural field, smart irrigation system has been proposed by using fuzzy based decision support system on Hyperspectral Image benchmark dataset. Hyperspectral images are the process of collected and processed the images from electromagnetic spectrum. Recent studies show that hyperspectral images are very accurate in collecting the soil moistures value. Dataset is collected in five-day field of campaign the soil is the type of clayey slit and it is non vegetation. Hyperspectral datasets which consist of range value between 454 to 598 nm. Value is gathered from the 285 hyperspectral snapshot camera recording images with 125 spectral bands with the spectral resolution of 4 nm. Experimental results of this method achieve the accuracy of 0.98. Hence the proposed method reduces the water wastage to an extent.

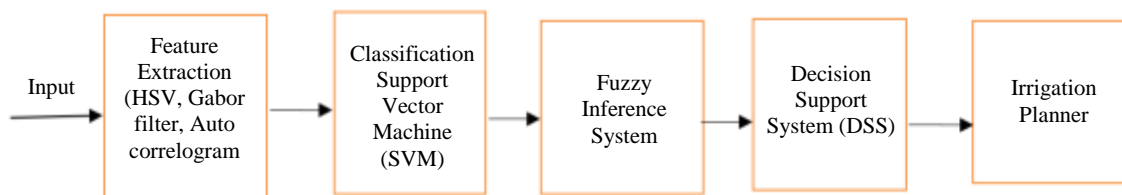
**Keywords:** Hyperspectral, Fuzzy Logic, Smart Farming

## Introduction

In recent years, the efficient utilization of water in agriculture is the most important challenges in modern agriculture (Polak *et al.*, 2017). In India, the rate of agriculture is poor, because of the nutrient contents and wastage of water or wrong irrigation practices. Smart agriculture system has been developed in now-a-days with the help of Hyperspectral images. This emerging technology is the first step for the application like agriculture, pharma and other fields (Zhong *et al.*, 2015). Hyperspectral imaging has distinguished itself among the more developed systems used to gather extensive scale information about an object without physical or closer contact with the object and also used to identify the minerals and vegetation content in soil (Cao *et al.*, 2017a). Hyperspectral sensors are used to collect remote images with the high resolution. It often captures hundreds of bands for each pixel. Pixel resolution is taken as 10nm and it has dozens and hundreds of visible and infrared ranges (Riese and Keller, 2018). Each image is dividing into bands whereas all the bands do not contain the information. Only selective bands will contain the information. Irrelevant bands are available that decrease the classification accuracy (Khan *et al.*, 2018). Soil moisture prediction model was mostly the study of different soil types such as clay, loamy, red soil, black soil etc. (Bandos *et al.*, 2009). There are many other

influencing factors like roughness, texture, mineral content is present in soil to analyze the soil moisture value but the result of soil moisture value is considered in the top layer of 5 cm (Zhong *et al.*, 2006). Data from the soil sensor is used to create the decision model (Govender *et al.*, 2007). The band selection is used to improve the performance of hyperspectral image classification (Breiman, 2017). Many methods to find the soil character and the soil types such as linear regression, Support Vector Machine (SVM), Decision tree. Support vector is mainly used for estimate the soil moisture content in hyperspectral images (Wark *et al.*, 2007).

Fuzzy logic system has an ability to represent the subjective knowledge in mathematical model (Majone *et al.*, 2013). The main objective of fuzzy based rules of inference is to find the amount of water required for the field that reduces the wastage of water content drastically. Numerous elements, for example, defective imaging optics, climatic disturbances, optical brightening impacts and sensor noise cause the corruption of the procure image quality, making spatial determination the costlier one and hardest to improve in imaging frameworks (Neamatollahi *et al.*, 2017). Supervised Learning uses the hyperspectral data (Cao *et al.*, 2017b). In fuzzy logic, the input and output relation are expressed by the set of linguistic rules. IF-THEN rules are employed to express conditional statements that constitute fuzzy logic (Martinez-Agirre *et al.*, 2017).



**Fig. 1:** Workflow diagram of proposed System

However fuzzy logic is used for prediction either yes/no or true/false based on the rules (Roseline *et al.*, 2012). Choosing the good prediction is the complex process however assuming the simple linear regression may lead to poor prediction. Non-linear prediction is needed to improve the accuracy of soil moisture from hyperspectral data.

Mostly fuzzy based system is consisting of four parts such as fuzzifier, de-fuzzifier, inference system and rule generator (Webber *et al.*, 2016). Hyperspectral imaging widely used in remote sensing applications, which involves complex surface measurements and detection of identical materials having fine spectral signatures (Palacios-Orueta and Ustin, 1998). This fuzzy system cannot be focus only on water management it also can be supported for selected crops. Based on the crop, rules are formed and the inputs are specially gathered for the selective crops (Jadhav and Patil, 2014). Input data are collected from the special dataset with the high-resolution images and with the high accurate data (Riese and Keller, 2018).

## Existing System

The soil classification is the main area to increase the crop yield. Soil classification is carried out by Support Vector Machine that classifies the type of soil by extracting the features from the soil image. Fuzzy rules are collected based on the experience of farmers to design the rules for the irrigation management. The suggested fuzzy rules are used to reduce the water waste and make the system to react according to weather monitoring system. This system is a user-friendly since it releases the water according to the need of the land and crops.

## Proposed Work

The Proposed methodology is the combination of wireless sensor network and fuzzy logic (i.e., Mamdani). Initially, noise has been removed from the input image using Gabor filter and low pass filter. Then, features are extracted from the image as statistical parameters like Auto correlogram, HSV Histogram, Standard deviation, Color moments, mean amplitude, energy, Temperature, Humidity and Wavelet transform. Finally, the irrigation quantity has been outputted based on the fuzzy rules. The overview of the proposed system is depicted in Fig. 1.

## Hyperspectral Datasets

Hyperspectral Datasets is measured in five-day field over two weeks. Dataset is taken from snapshot of camera recording of 50 by 50 images with 125 spectral bands with the range from 450 nm to 950 nm with the resolution of 4 nm. Soil sample is taken from the sensor with the radius of 15 cm and with the height of 20 cm (Riese and Keller, 2018).

## Classifications

### Decision Tree

Decision Tree is a statistical/machine learning technique for classification and regression. It is mainly used for interaction between the variables and new data. This method makes an accurate prediction for new data. Best accuracy value is calculated as 0.88861 in the fine tree method. Table 1 shows the decision tree types and their properties employed in this work.

### Support Vector Machine (SVM)

Support Vector Machine is a selection method that compares the standard parameter set of discrete values, called the candidate set and takes the one that has the best classification accuracy. Best accuracy value is calculated as 0.55662 in the Fine Gaussian method compared with all the other SVM methods. Table 2 shows the SVM variants available in matlab toolbox.

### Linear Regression

Learning a linear regression means estimating the values of coefficient that is used to represent the data. It is a machine learning model. Mainly it is used for finding the relationship between variables and forecasting. There are different regression models that it based on the relationship in data between dependent and in dependent variable.

### Robust Regression

Regression analysis finds the relationship between one or more independent variable and the dependent variable. Robust regression method is designed for not affecting the violations underlying the data generating process.

### Stepwise Regression

Stepwise regression is the combination of both forward and backward selection technique. It contains

the multi variate selection procedure it will perform usually a better.

*Comparison of RMSE and R<sup>2</sup>*

RMSE is an error value by performing the mean operation and whereas R<sup>2</sup> means taking the square for all the mean values. Values are calculated using the

regression learner app in MATLAB which includes all the regression models. RMSE and R<sup>2</sup> value has been compared for 285 hyperspectral snapshots. This comparison gives the best and worst fit regression value from the band datasets. Classification is carried out with different feature selection in the ratio of 39, 29 and 25, 20, 15, 10. Table 3 and 4 represents the feature selections.

**Table 1:** Decision tree types

Properties	Coarse tree	Medium tree	Fine tree
Flexibility	Low	Medium	High
Splits	4	20	100
Prediction	Fast	Fast	Fast

**Table 2:** SVM variants

SVM Variants	Prediction speed		Memory usage		Interpretability
	Binary	Multiclass	Binary	Multiclass	
Linear SVM	Fast	Medium	Medium	Medium	Easy
Quadratic SVM	Fast	Slow	Medium	Large	Hard
Cubic SVM	Fast	Slow	Medium	Large	Hard
Fine Gaussian SVM	Fast	Slow	Medium	Large	Hard
Medium Gaussian SVM	Fast	Slow	Medium	Large	Hard
Coarse Gaussian SVM	Fast	Slow	Medium	Large	Hard

**Table 3:** Features selection 39, 29, 25

Number of Features Selection		39		29		25	
Classification	METHOD	RMSE	R <sup>2</sup>	RMSE	R <sup>2</sup>	RMSE	R <sup>2</sup>
Decision Tree	Fine Tree	0.88861	0.94	1.0083	0.92	1.0094	0.92
	Medium Tree	0.97815	0.93	1.0569	0.92	1.0383	0.92
	Coarse Tree	1.3896	0.86	1.3155	0.87	1.3155	0.87
SVM	Linear SVM	1.5509	0.82	1.4992	0.83	1.5034	0.83
	Fine Gaussian	0.5562	0.98	3.6366	0.01	1.6168	0.80
	Coarse Gaussian	1.9092	0.73	1.5082	0.83	1.4431	0.84
	Medium Gaussian	1.0225	0.92	1.4782	0.86	1.2803	0.88
Regression	Linear	1.4679	0.84	1.4354	0.85	1.4237	0.85
	Robust Linear	1.742	0.77	1.711	0.78	1.704	0.78
	Stepwise Linear	1.411	0.85	1.367	0.86	1.860	0.52

**Table 4:** Features selection 20, 15, 10

Number of features section		20		15		10	
Classification	METHOD	RMSE	R <sup>2</sup>	RMSE	R <sup>2</sup>	RMSE	R <sup>2</sup>
Decision Tree	Fine Tree	1.0093	0.92	0.9890	0.93	0.72258	0.96
	Medium Tree	1.0383	0.92	1.0369	0.92	0.77034	0.96
	Coarse Tree	1.3155	0.87	1.3155	0.87	1.2595	0.88
SVM	Linear SVM	3.5884	0.83	1.5209	0.83	1.7787	0.76
	Fine Gaussian	3.5884	0.03	3.3637	0.15	3.2494	0.21
	Coarse Gaussian	1.4431	0.84	1.3608	0.87	1.6388	0.80
	Medium Gaussian	1.2803	0.88	0.9890	0.93	0.72258	0.96
Regression	Linear	1.4237	0.85	1.0369	0.92	0.77034	0.96
	Robust Linear	1.704	0.78	1.3155	0.87	1.2595	0.88
	Stepwise Linear	1.203	0.22	1.5209	0.83	1.7787	0.76

### Comparison Result

Table 5 shows the Comparison result of Classifications method shows less RMSE values and higher  $R^2$  values. Hence it is a suitable classifier for soil classification when compared with the previous methods. Experimental results show that SVM provides the better values compared with all the other classification mechanism.

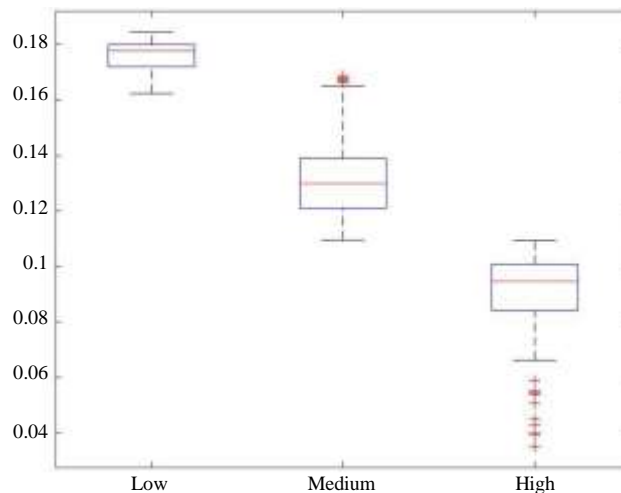
### Fuzzy

Fuzzy Logic is a logical system and it is an extended value of multi valued logic. It is the concept of set of fuzzy values and mainly used for decision making process. Input value is processed as manual partition and passed to the decision system. Then, Fuzzy is used for making the decision for the quantity of water that should serve for farming land. Based on the soil moisture value the quantity is decided. Fuzzy rules are formed based on the partition of data. At the

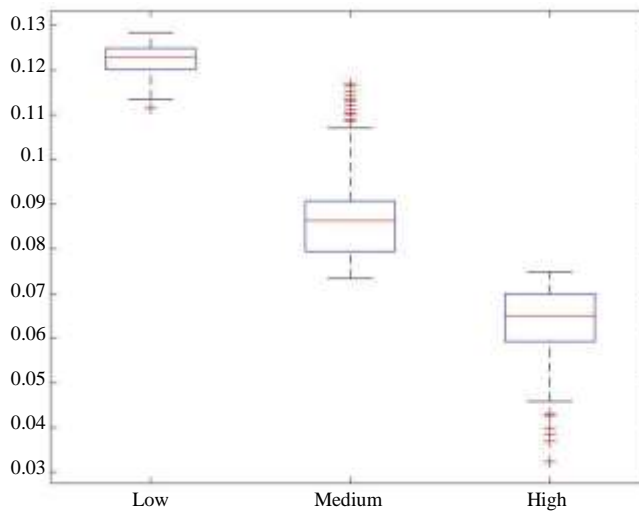
time of execution, the rules are evaluated based on the quantity of water. Decision making system is range of Conditions as YES/NO or TRUE/FALSE or 0/1. Soil moisture is the important feature in the rules.

Table 6 shows the soil moisture range value. Based upon this soil moisture, the quantity of water has been decided. These data were measured in spectral band in various band measures. The box plot represents the upper and lower quartiles, while inside the line represents the median value. In Fig. 2, box plots shows how efficiently discriminate soil moisture such as low, medium and high using spectral band values.

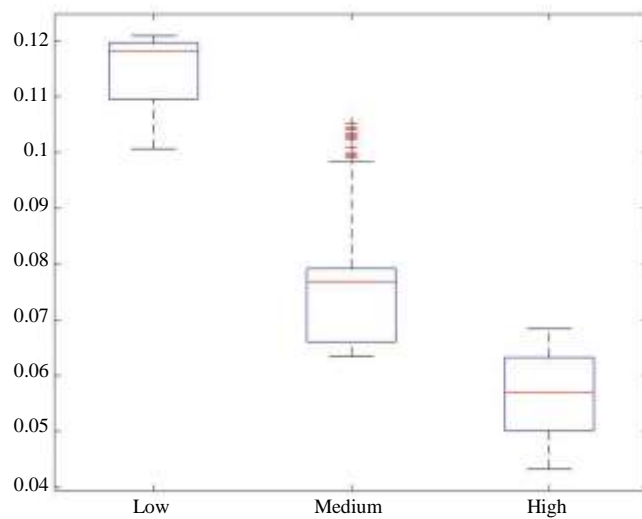
The Fig. 3 shows the hyperspectral data for soil moisture. The plot represented by x and y values, x shows range of values whereas y represents soil moisture types. Figure 3 (a) Depicts the plot for low water management system (b) depicts the plot for medium water management system (c) depicts the plot for high water management system (d) depicts the plot for no water management system.



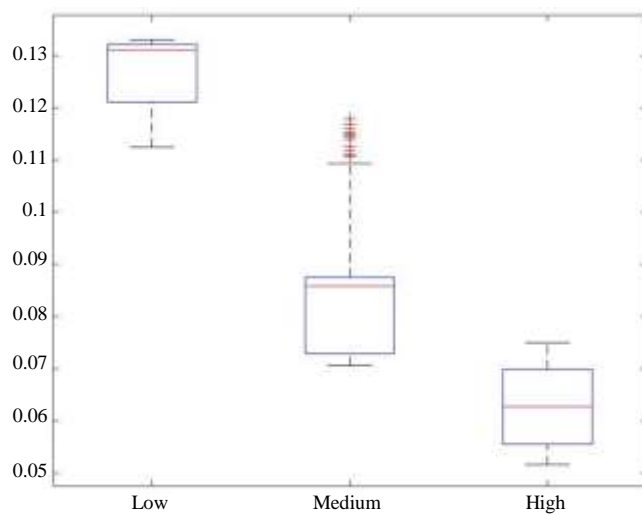
(a)



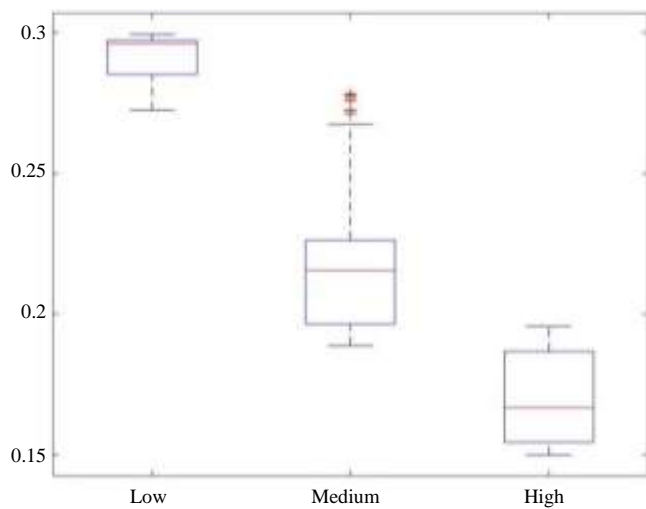
(b)



(c)

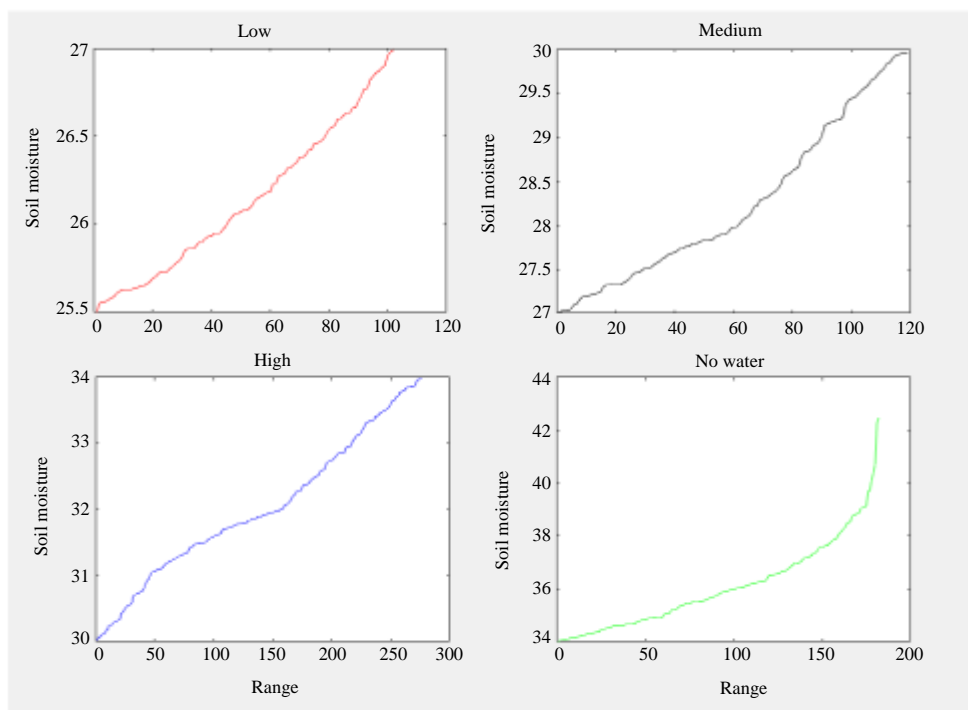


(d)



(e)

**Fig. 2:** Box plots of 454, 458, 494, 510 and 874 spectral band for soil moisture classification of hyperspectral data



**Fig. 3:** Plot of range values

**Table 5:** Comparison result of classifications

METHOD	RMSE	R <sup>2</sup>
Decision Tree	0.88861	0.94
SVM	0.55662	0.98
LR	1.46790	0.84

**Table 6:** Soil moisture range value

Moisture Range	Linguistic variable
25 ≤ x < 26	LOW
26 ≤ x < 29	MEDIUM
29 ≤ x ≤ 33	HIGH

## Conclusion

The contribution of this paper is to minimize the water wastage and improve the accuracy of water management. Data are collected from the experienced farmers as well as the researchers. Rules are framed from the collected data. These rules were used to make decisions in the fuzzy system. By taking the factors as input to the fuzzy system is Soil moisture. This input is given to the fuzzy inference system which chooses the amount of water for an optimum output Result from the different regression methods clearly states that SVM gives the better accuracy value. In Future, this system can be extended for the optimization of chemical wastage in farming using the fuzzy inference system.

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## Author's Contributions

All authors are equally contributed in this work and this paper.

**Santhi Balachandran:** Planned and carried out the experiments.

**Sourna Lakshmi:** Participated in data collection and feature selection.

**Nithya Rajendran:** Participated in performance evaluation.

## Ethics

This article is original and contains unpublished material. The corresponding authors have read and approve the manuscript and no ethical issues involved.

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