Journal of AgriSearch, 9 (2):157-159
An Open Access International Peer Reviewed Quarterly

ISSN : 2348-8808 (Print), 2348-8867 (Online)
https://doi.org/10.21921/jas.v9i02.10123

Land Use and Land Cover Classification using Fuzzy Logic for better Accuracy: A Case Study of Ranchi

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ABSTRACT

The aim of present study is to classify the LISS III (Linear Imaging Self Scanning Sensor) image of Ranchi area of February, 2015 using standard maximum likelihood (ML) and fuzzy logic for different land use and land covers (LULC). Fuzzy logic is relatively a new concept. Now, fuzzy logic is widely used in the classification of remotely sensed images for various land use and land cover classes of mixed pixels where as standard ML classification method is unable to classify mixed pixels. Classification of images mainly includes five LULC classes viz. standing water bodies, natural vegetation and agricultural lands, dense built-up and low-density built-up area. Dense built-up area is mainly related to urban area and low built-up area is of rural areas. Image classification performed first using ML supervised and then in fuzzy logic approach. Producer's accuracy, user's accuracy, total accuracy, and kappa coefficients were calculated and tested for standard and fuzzy supervised classifications. Standard classification procedures have an overall accuracy of 86.12 percent, while fuzzy classification approaches have an accuracy of 91.56 percent. A kappa coefficient for standard method of classification is 0.84 where in fuzzy approach of classification, the kappa coefficient is 0.89. So on the basis of overall accuracy and kappa coefficients; it has been observed that the fuzzy classification technique provides better accuracies than the standard ML supervised classification approach.

Keywords: Image, classification, accuracy, land use and land covers.

ARTICLE INFO

Received on	:	30.03. 2022
Accepted	:	31.05. 2022
Published online	:	16.06.2022

INTRODUCTION

Image classification is the process of sorting pixels into a finite number of individual classes, or categories of data based on their data file values. If a pixel satisfies a certain set of criteria, the pixel is assigned to a class. Digital image consists of discrete picture elements called pixels that are associated with a digital number as DN value that depicts the average radiance of image area. The range of DN value is normally 0 to 255. Digital image processing is a collection of techniques for the manipulation of digital images by computers. Classification generally comprises of pre-processing, training selection, area of interest creation, choice of suitable classification algorithm and accuracy assessment using confusion matrices. Land use and land covers are two different things (Dimyati *et al.,* 1996). Land cover refers to the physical materials on the surface of land viz. natural vegetation, barren land, natural water bodies, etc. while land use refers to the human activities that takes place to use land, e.g., residential, industrial, commercial, agricultural land (Longley *et al.,* 2001). Image classification is a process to assemble groups of identical pixels in remotely sensed data into one LULC class (Palaniswani *et al.,* 2006). Classification accuracy is calculated with the help of confusion matrix that are producer's accuracy, user's accuracy, overall accuracy and the Kappa coefficient (Jenssen and Van der wel 1994). Fuzzy logic is a new way to solve mathematical as well as classification problems using a degree of membership (Zadeh 1965). A fuzzy set is a set whose elements have degrees of membership that can be full member or a partial member. So the membership value assigned to an element is not restricted to just two values as 0, 1 along with any value in-between 0 and 1. Mathematical function which defines the degree of membership of an element in a fuzzy set is called membership function. The problem description is in linguistic terms, rather than in terms of precise numerical values is the major advantage of fuzzy logic. Fuzzy logic comes under soft where as ML method is hard image classification technique. Soft image classification technique is used to classify mixed pixels but ML method is unable to classify mixed pixels.

The aim of this study was to determine the accuracy of the classification of land use and land cover features of various classes/ categories as obtained by the LISS III images of February 2015 of Ranchi area. A fuzzy logic technique is applied for the classification of land use and land cover using remote sensing imagery and the evaluation of classification accuracy. An idea to solve the problem of image classification in fuzzy logic approach as well as comparison of the results of supervised standard maximum likelihood (ML) and fuzzy supervised classification was the main objective of this work. Standard and fuzzy classifications were done and tested on the basis of calculating producer's accuracy, user's accuracy overall accuracy and kappa coefficients. LULC classes are standing water body (SW), natural vegetation (NV), agriculture land (AG), dense built-up (DB) and low built-up (LB). Dense built-up area is mainly considered as urban area and low built-up area is considered as rural area. In the month of February, maximum area of agricultural land remains

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fallow (rice fallow) due to less availability water resources for irrigation. But in some area, farmers grow vegetables, linseed, etc. as per availability of water and using drip and sprinkler irrigation to irrigate crops to grow more crops in less water and the income of farmers is also increased.

MATERIALS AND METHODS

Study Area

The area considered for this research includes Ranchi city and its surrounding. The area of interest is situated in between 23º16'N to 23º30'N and 85º13'E to 85º32'E. The study area Ranchi is located on the southern part of Chotanagpur plateau forms the eastern part of the Deccan plateau. Subarnrekha river and its tributaries constitute the local river system. Dams in Kanke, Rukka and Hatia have been built to fulfill water requirement of majority of population. It has humid subtropical climate. Temperature ranges from 20º to 42ºC in summer and from 0º to 25ºC during winter. The annual rainfall is about 1295mm. The entire district of Ranchi covered by red soil except for a small portion in the south east which contains red and black soil. Forest cover is a considerable portion of the district. The trees found along with Sal trees are Gamhar, Kend, Simul and Mahua.

Data Used

IRS LISS III data of February, 2015 of 4 bands (Red, Green, NIR and SWIR) having spatial resolution of LISS III data is 23.5 m, and bandwidth ranges from 0.52-0.59 µm, 0.62-0.68 µm, 0.77-0.86 µm, 1.55-1.70 µm. Temporal resolution is of 24 days that enables proper identification of land use and land covers. Classification of images has been done by using supervised standard maximum likelihood and fuzzy methods.

Methodology

First, preprocessing of images is done that include geometric correction, atmospheric correction, radiometric calibration and radiometric rectification procedures to facilitate comparability between dates (Jensen, 1996). After preprocessing of image, georeferencing has been done. Georeference means to define the existence of an image in a physical space to establish its location in terms of map projections or coordinate systems. In our study, the satellite image of year February, 2015 were georeferenced with the help of the GCPs identified on the corresponding to Survey of India toposheet No. 73E/7.

Supervised maximum likelihood and fuzzy classification:

The maximum likelihood (ML) classification method applied probability theory for the classification work. From the training set of classes, the method determines the class centers and the variability in raster values in each input band for each class. This information allows the process to determine the probability that a given cell in the input set belongs to a particular training class. The probability depends upon the distance from the cell to the class centre. The maximum likelihood method computes all of the class probabilities for each raster cell and assigns the cell to the class with the highest probability value. This method, however, needs more computations to classify each pixel than other methods like the minimum distance to mean and parallelepiped classifiers (Campell 1996; Lillesand and Kiefer 2000; Clark Labs 2001) but it provides better results. The supervised classification method requires the user to develop the spectral signatures of known categories, while the software assigns to each pixel in the image a category to which its signature is most similar. In supervised classification, the user has some control and feature classes are pre-defined by users. In supervised classification techniques, training areas are defined by the user in order to determine the characteristics of each feature class or category. Each pixel in the image is assigned to one of the classes. In this classification, the image pixels that represent the individual class are collected and characteristics are also calculated from these training samples. Area of interests (AOIs) are created after preprocessing, training sample and signature collection of the LISS III image of February, 2015 & have been classified using training signatures applying supervised standard maximum likelihood and fuzzy logic technique. Five classes have been taken in to considerations that are standing water body (SW), natural vegetation (NV), agriculture land (AG), dense built-up (DB) and low built-up (LB). Producer's accuracy, user's accuracy, overall accuracy and kappa coefficients have been calculated for classified images from confusion matrices. Confusion/ contingency matrices show producer's accuracy, user's accuracy, overall accuracy of the different classes. Kappa coefficient values have also been calculated for all classified images and in accuracy assessment the classification process is incomplete. The accuracy of this classification has been assessed through confusion matrix. Confusion matrices compare different categories of an automated classification with the known reference data or ground truth (Congalton and Green 1999). At last comparison of accuracies has been done in between images classified by supervised ML and fuzzy techniques and it is expected that the fuzzy classified images should provide better accuracy than the images classified by ML method.

RESULTS AND DISCUSSION

Once the images of February, 2015 through supervised standard ML and fuzzy techniques using training signatures. After classification of images, confusion matrices are created and utilized to assess producer's accuracy, user's accuracy and overall accuracy and Kappa coefficients of all classified images. Comparative analysis among producer's accuracy, user's accuracy, overall accuracy and kappa coefficients have been done. Standing water exhibits 100% producer's and user's accuracy for both fuzzy and standard techniques (Table 1 & 2). Natural vegetation exhibits second higher producer's accuracies than agriculture, dense built-up and the low built-up exhibits the lowest accuracy. It has been observed that the

Table 1: Producer's Accuracy for both classification techniques for LISS III imagery of February 2015.

Year	2015	
Categories	ML	FL
SW	100	100
NV	92.65	94.24
AG	88.34	90.62
DB	86.23	88.12
LB	84.54	86.72

Where, SW: Standing Water Body; DB: Dense Built-up; LB: Low Built-up; NV: Natural Vegetation; AG: Agriculture Land; ML: Maximum Likelihood; FL: Fuzzy Logic

Table 2: User's Accuracy for both classification techniques for LISS III imagery of February 2015

Year	2015	
Categories	ML	FL
SW	100	100
NV	91.84	93.87
AG	89.65	91.52
DB	87.82	89.72
LB	83.64	84.92

Where, SW: Standing Water Body; DB: Dense Built-up; LB: Low Built-up; NV: Natural Vegetation; AG: Agriculture Land; ML: Maximum Likelihood; FL: Fuzzy Logic

overall accuracies of images classified using fuzzy technique are more than the accuracies of images using standard supervised ML classification technique. The values of kappa coefficients of fuzzy classified images are also higher than the ML classified images (Table 3).

Table 3: Overall Accuracy and Kappa coefficients for both classification techniques for LISS III imagery of February 2015

Overall Accuracy		Kappa coefficients	
ML	FL	ML	FL
86.12	91.56	0.84	0.89

CONCLUSION

With the use of a confusion matrix, the producer's, user's, overall accuracies, and the value of kappa coefficients for each categorized image were calculated for both traditional ML and fuzzy approaches. Following that, a comparison was made between the accuracy of the producer, the accuracy of the user, the overall accuracy, and the value of the kappa coefficients of the various classes established from the categorization of the image viz. supervised techniques such as standard maximum likelihood and fuzzy supervised classification. From the aforementioned data, it can be shown that the fuzzy logic method provided greater accuracies than the accuracies classified using normal maximum likelihood procedures. As a result, the fuzzy classification method outperforms the usual maximum likelihood method.

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Citation:

Manibhushan, Upadhyaya A, Singh AK and Kumari A. 2022. Land use and land cover classification using fuzzy logic for better accuracy: A case study of Ranchi. *Journal of AgriSearch* **9**(2):157-158