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Land use/Land cover Classification of Modjo River Catchment, Upper Awash Basin, Central Ethiopia

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ABSTRACT

LULC maps play a significant and prime role in resource planning, management and monitoring in the formation of policies and programme required for development. Satellite sensor images, also called remote sensing images, due to their synoptic view, are a viable source of gathering effective land cover information. In this study the LULC based on the satellite image of years 2021 using remote sensing and GIS application where identify for Modjo river catchment. Hence the satellite images for this particular study were acquired from ETM+ images obtain from FAO Afrikaner database http://www.africover.org./index.htm.web site, which is a FREE Global Orthorectified Landsat Data accessing site via FTP. ArcGIS10.2 were used to process the satellite image and the identity of each class is determined by the combination of experience and ground truth. FISHER classifier technique of supervised image classification technique was applied to uncover commonly occurring and distinctive reflectance patterns in the imagery, on the assumption that these represent major land cover classes since the classes are known at the outset. Consequently valuable LULC Map were developed for Modjo river catchment. From the result, in Modjo river catchment five land use/cover such as agricultural land1086 km^2, grassland 363 km^2, Tree & Shrub 330 km^2, Water body 154 km^2 and Settlement 242 km^2 of the total catchment area have identified and illustrated with different colors on the map. The Map can be utilized in formulating sustainable land development activity as well as in mitigating the challenges of land-degradation in the catchment.

Keywords: LULC Map; ArcGIS; Modjo River Catchment; Satellite Sensor Images.

1. Introduction

Land Use/Land Cover (LULC) refers to the categorization or classification of human activities and natural elements on the landscape within a specific time frame based on established scientific and statistical methods of analysis of appropriate source materials (SATPALDA, 2022). It is the use of land via agriculture, conservation, development, recreational places, wildlife habitats, and urban regions or any other activity and the outcome of human-environment interaction in a particular location, as influenced by climate change processes and socioeconomic dynamics (Prakasam 2010, Reis 2008 and Rawat 2015).

LULC maps play a significant and prime role in ***planning, management and monitoring programmes*** at local, regional and national levels. This type of information, on one hand, provides a better understanding of ***land utilization aspects*** and on the other hand, it plays an important role in ***the formation of policies and programme required for development planning***.

LULC maps also help us to ***study the changes*** that are happening in our ecosystem and environment and it establishes the baseline information for activities like thematic mapping and change detection analysis. Traditional methods of land cover mapping have been limited to field surveys that are time-consuming and uneconomical with data collected over long time intervals. The methods are particularly inefficient and impractical for real-time global and regional land cover mapping.

Satellite sensor images, also called remote sensing images, due to their synoptic view, are a viable source of gathering effective land cover information. Remote sensing is the main source for several kinds of thematic data critical to GIS analyses, including data on landuse and landcover characteristics. Aerial and Landsat satellite images are also frequently used to evaluate land cover distribution and to update existing geospatial features (Merchant, J.W. and Narumalani, S. 2009).

This study aims to articulate the classification of LULC in a fast growing industrial area of Modjo river-catchment. The main focuses of this study is to identify the LULC based on the satellite image of years 2021 using remote sensing and GIS application. This study is expected to contribute to the decision maker in making a better emergency response and plan towards sustainable land development activity as well as mitigating the challenges of land-degradation due to less natural resource conservation in the catchment.

2. Material and Methods

2.1. Description of study area

This study was conducted for Modjo River catchment, which is located at upper Awash Basin. The sub-basin covers about 2201 km^2 area and is bounded within 8°75'N-9°05'N latitude and 38°56'E -39°17'E longitude. Elevation for the catchment ranges from 1594 to 3068 meter above mean sea level. The area has a bi-modal rainfall with a short rainy season from March to May and with a long rainy season from June to September. The mean annual temperature of the sub-basin is 19°C and the average annual rainfall is 933 mm. The relief of the study area is generally flat land with an undulation of some ridges and mountains like eastern part of Yerer and the catchment generally shows an eastward decrease in elevation. The water units found in the study area are Modjo and Gale Wemecha Rivers. Regarding geological set up, the area belongs to the Quaternary rocks of Pleistocene and Holocene which is 70% quaternary volcanic rock and 30% unconsolidated sediment. According to WSP (2006), those rocks are highly fractured rocks and resulted a favorable situation for groundwater recharge and occurrence and are very important hydro-geological formation that are used as good source of groundwater in Ethiopia.

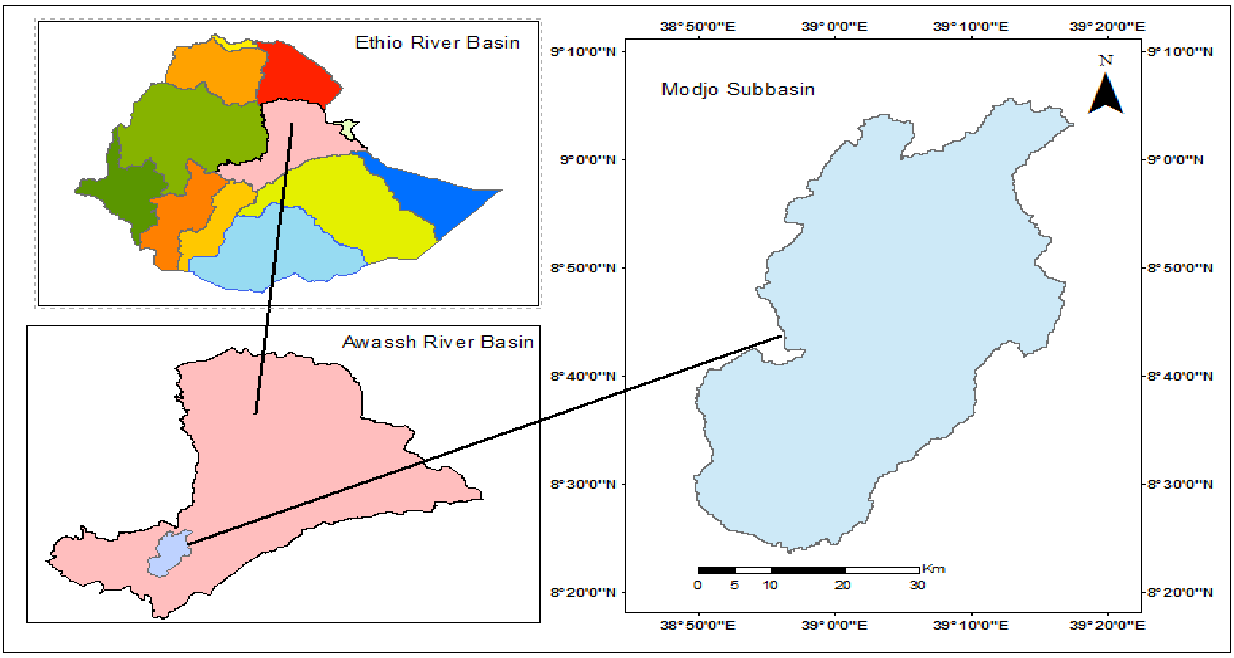

Figure 1. Location map of Modjo Sub-basin

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2.2. Image Pre-Processing

2.2.1. Data Preparation

The satellite images for this particular study were acquired from ETM+ images obtain from FAO Afrikaner database http://www.africover.org./index.htm.web site, which is a FREE Global Orthorectified Landsat Data accessing site via FTP. Images for the study area were downloaded at *path68 rows 53 and 54* acquired on the 27th of January 2021, for winter season land use and on the 5th of July 2021 for summer season land use. ArcGIS10.2 were used to process the satellite image and the identity of each class is determined by the combination of experience and ground truth. The following figures illustrate the satellite image of Modjo river catchment and its surrounding from ETM+ sensor in different time.

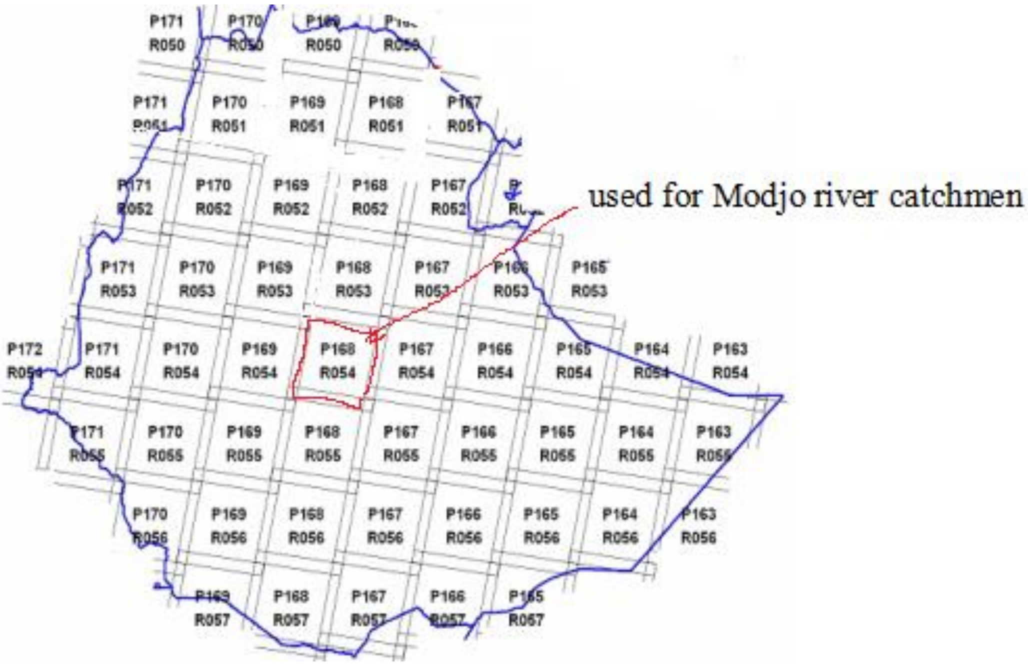

Figure 2. ETM+ data path (p) and row (r) indicator map for the whole of Ethiopia

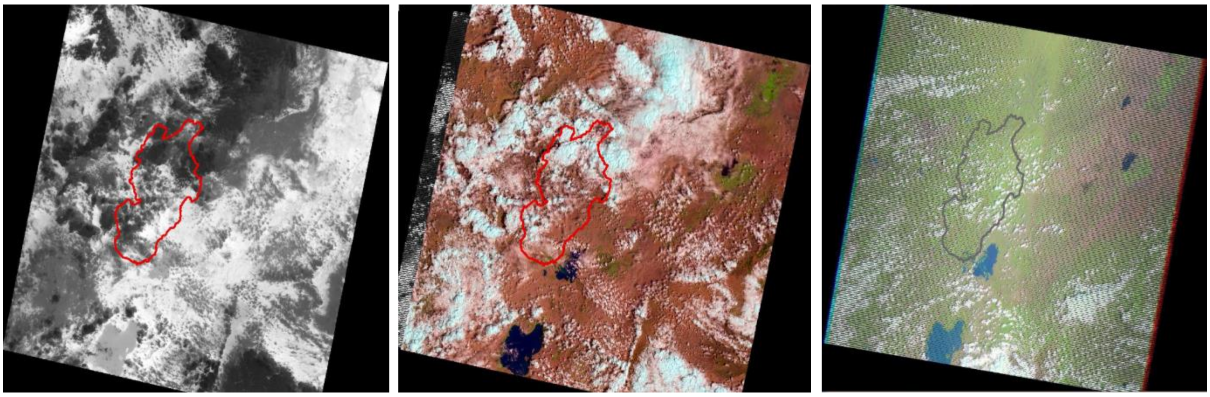

Figure 3. Visible land use classes satellite image of Modjo sub-basin and its surroundings

FISHER classifier technique of supervised image classification technique was applied for this study to uncover commonly occurring and distinctive reflectance patterns in the imagery, on the assumption that these represent major land cover classes since the classes are known at the outset.

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The steps for supervised classification may be summarized as follows (Ronald, 2001).

(i) Locate representative examples of each cover type that can be identified in the image (gcp),

(ii) Digitize polygons around each ground control point (gcp),

(iii) Assign a unique identifier name to each cover type after digitizing the polygons, analyze the pixels within the ground control point (gcp),

(iv) Create spectral signatures for each of the cover types,

(v) Classify the entire image by considering each pixel, one by one, comparing its particular signature with each of the known signatures by the help of classifiers.

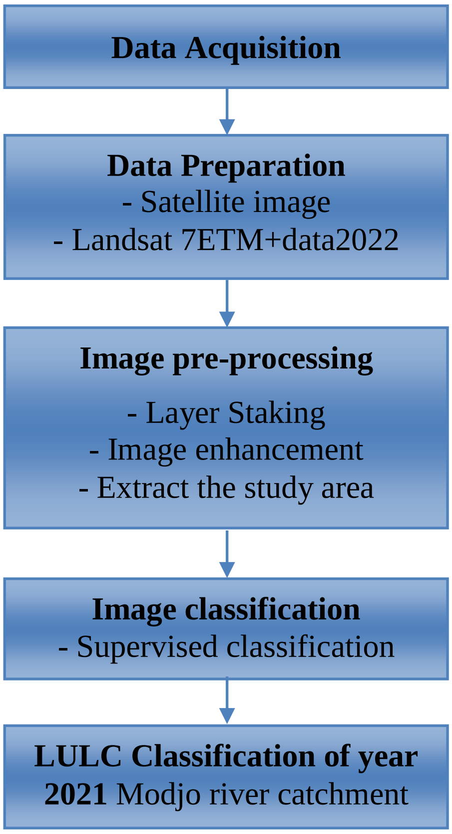

Figure 4. Flowchart for The land use land cover (LULC) mapping process of Modjo river catchment

2.2.2. Image correction and enhancement

For appropriate satellite image analysis, two types of correction are required: radiometric correction and geometric correction. In this study all of the satellite images used were taken at Level 1, which indicates that no data had to be processed for geometric correction and that the information had already been orthorectified (P.K. Srivastava, D. Han 2012). The interpreter's visual impact is enhanced by satellite picture augmentation, which also improves the material. The image improvement technique includes resolution enhancement, contrast enhancement, IHS (Intensity, Hue, and Saturation) transformation, density slicing, edge enhancement, digital mosaics, and synthetic stereo images (S.N. Ahuja, S. Biday, 2018). Contrast Enhancement and Intensity, Hue, and Saturation Transformation techniques have been used to enhance the image for visualization and analysis in this study. One of the most

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important parts of image processing is contrast enhancement, which is frequently highlighted. The objective is to maximize contrast in a picture so that all of the information in the input image can be represented. General histogram equalization, decorrelation stretching, and gamma correction were utilized in this work to enhance the visual interpretation of land cover classes. The image color method was transformed from RGB to IHS system and the adjustment was altered to perceive the difference better during the enhancement using the Intensity, Hue, and Saturation Transformation approach (T.M. Lillesand 2004).

3. Results and Discussions

3.1. Color composite image generation

By selecting three bands from a multi-band image and illuminating each of them with red, green, or blue light we can create a color image. Many images that are acquired using remote sensing instruments can have dozens or even hundreds of bands .To make a color image from images that have several bands we need to select three bands that can be assigned to the three color channels in a computer monitor. In addition to the information from the explanation given about some of the features of the eight Landsat 7 Enhanced Thematic Mapper Plus (ETM+) bands and how they are tailored for detecting different features the principal component analysis (PCA) where used to distinguish the three important bands to form color composite image. The module composite, where then used to construct three-band color composite image.to create the composite image from three input bands, each of the three bands is stretched to 5 levels (5 * 5 * 5 = 125). The composite image consists of color indices where each index = blue + (green * 5) + (red * 25) assuming a range from 0-4 on each of the three bands

3.2. Principal component analysis (PCA):

PCA is undertaken on a set of image bands to produce a new set of images - components that are uncorrelated with each other and explain progressively less of the variance found in the original set of bands. The technique is used for data compression since the first two or three components explain much percent of the variance in the original set of bands. In cases like this, the components explaining less than a certain percent of the variance can be dropped. One application of Principal Components Analysis then is data compaction—by retaining only the first few components one can keep most of the information while discarding a large proportion of the data. For the purpose of this project Bands 5 and 7 are excluded from the PCA since their resolution is different from the rest of the bands, and Band 3 is excluded due to the special strange feature (image noise) appeared on it.

Table 1. Principal component analysis (PCA) result of Bands

VAR/COVAR	band1	band2	band4	band6	band8
band1	123.05	170.23	267.12	328.52	278.05
band2	180.93	255.61	410.91	517.38	432.61
band4	265.23	420.91	696.41	867.44	702.87
band6	302.41	532.66	856.28	1352.76	1087.89
band8	246.33	432.73	712.64	1023.49	912.25

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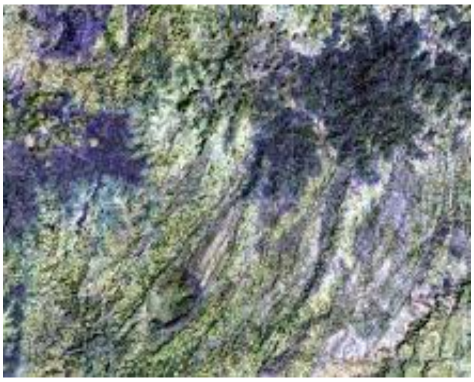

Figure 5. Color composite image of Modjo river catchment and its surroundings

3.3. Training site development

The first step in undertaking a supervised classification is to define the areas that will be used as training sites for each land cover class. Training sites are based on the knowledge of land cover types identified on the color composite image and using the GPS records collected from the region. The color composite image can be zoomed in to identify the pixel values of each land use types .

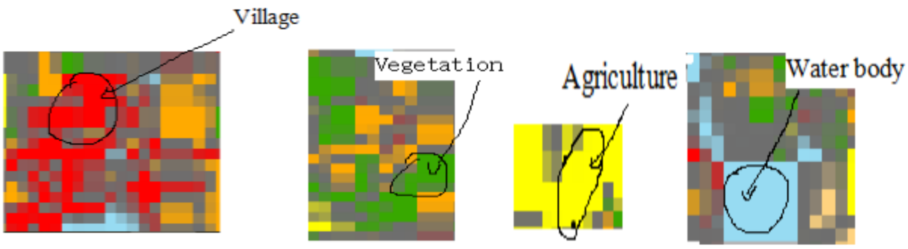

Figure 6. Typical signatures and training sites based on the color composite image

3.4. Land use classification

Fig 6 and 7 shows the summer and winter LULC map layout created from the Landsat 7 ETM+ of Modjo river catchment. Table 1 contains the area distribution of land use types in km^2 and percentages. According to this survey, in Modjo sub-basin agricultural land covers 1086 km^2, grassland 363 km^2, Tree & Shrub 330 km^2, Water body 154 km^2 and Settlement 242 km^2 of the total catchment area.

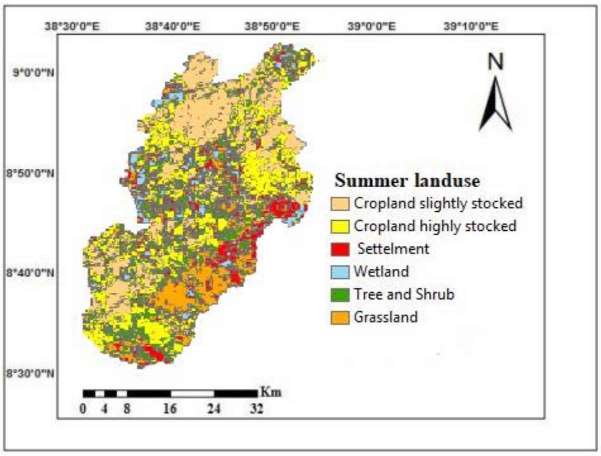

Figure 7. Land use/land cover map of Modjo subbasin during summer season

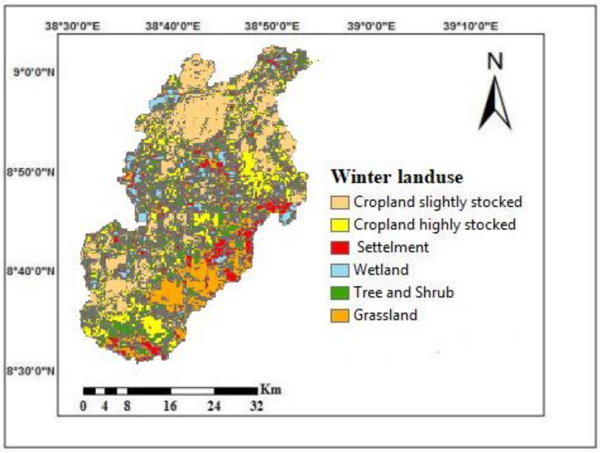

Figure 8. Land use/land cover map of Modjo sub-basin during winter season

Table 2. The area distribution of land types in % and km^2

No.	Land use class	Area km^2	Area coverage (%)
1.	Agriculture	1086	49.3
2.	Grassland	363	16.5
3.	Tree & shrub	330	15
4.	Water body	154	7
5.	Settlement	242	11

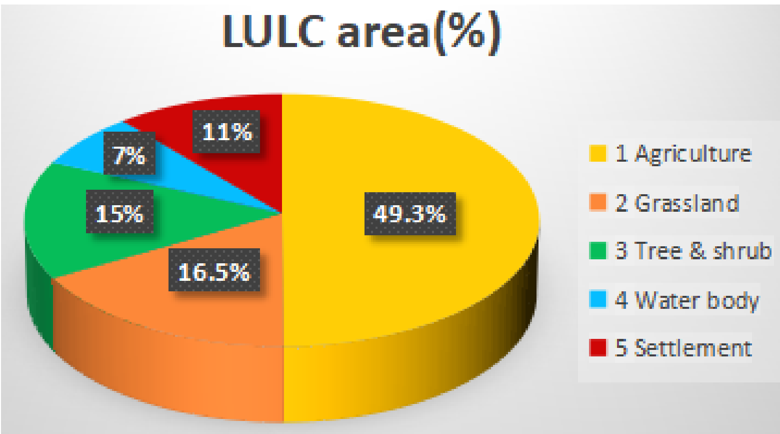

Figure 9. Pie chart showing the percentage of different land use categories

4. Conclusion

LULC maps play a significant and prime role in resource ***planning, management and monitoring*** in ***the formation of policies and programme required for development.*** Satellite sensor images, also called remote sensing images, due to their synoptic view, are a viable source of gathering effective land cover information. In this study the LULC based on the satellite image of years 2021 using remote sensing and GIS application where identify for Modjo river catchment. Hence the satellite images for this particular study were acquired from ETM+ images obtain from FAO Afrikaner database http://www.africover.org./index.htm.web site, which is a FREE Global Orthorectified Landsat Data accessing site via FTP. ArcGIS10.2 were used to process the satellite image and the identity of each class is determined by the combination of experience and ground truth. FISHER classifier technique of supervised image classification technique was applied to uncover commonly occurring and distinctive reflectance patterns in the imagery, on the assumption that these represent major land cover classes since the classes are known at the outset.

Consequently valuable LULC Map were developed for Modjo river catchment. The developed Map contributes for baseline information in formulating technically sound sustainable land development activity as well as mitigating the challenges of land-degradation due to less natural resource conservation in the catchment. According to this survey, in Modjo sub-basin agricultural land covers 1086 km^2, grassland 363 km^2, Tree & Shrub 330 km^2, Water body 154 km^2 and Settlement 242 km^2 of the total catchment area.

Declarations

Source of Funding

The study has not received any funds from any organization.

Competing Interests Statement

The author has declared no competing interests.

Consent for Publication

The author declares that he consented to the publication of this study.

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