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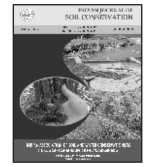

# Geospatial assessment and physical characterization of terraced low land (*Jhola* land) in Eastern Ghats Highland of India

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**ABSTRACT**

The aims of this study is to map spatial extent and characterization of *Jhola* land (terraced low land), using remote sensing (RS) and geographical information system (GIS) techniques. *Jhola* land is a very important land use system in Koraput district, Odisha in terms of rice production. For mapping, DEM, slope and stream network maps of the district were used as base maps. IRS-Linear Imaging Self Scanner (LISS) IV images of 2013 were also used for assessment of area under the land. Both supervised classification and visual interpretation of satellite images based on tone, texture, shape, association and on-screen digitization was carried out to identify *Jhola* land. The overall accuracy level was found to be more than 85%. The best NDVI for delineating *Jhola* land areas was observed to very between -0.08 and 0.43. *Jhola* land systems occur at or above 700 m elevation and are present in 10 blocks of Koraput district, occupying 186.7 km$^2$, which is 2.2% of the total geographical area of the district. Around 84% of total *Jhola* land systems originated either from 2$^{nd}$ or 3$^{rd}$ order streams. Suitable classification scheme of *Jhola* land was developed based on size, slope and pereniality. The developed data base on *Jhola* land system will help policy makers in making this system sustainable.

## 1. INTRODUCTION

Eastern Ghats Highland (EGH) region of Odisha, India covers an area of 1.25 M ha spreading over two districts of Odisha, namely Koraput and Nabarangapur, and supports about 2.13 million populations (Census, 2011). This region is characterized with diverse natural resources, human resources and socio-economic aspects (Sharda *et al.,* 2013). Majority of the population is predominantly tribal and is dependent on agriculture and land-based activities. The agricultural production system is mostly rainfed and mono-cropped. However, with changing requirements of burgeoning population, there is a tremendous pressure on the available land in terms of food production. In this part of Eastern Ghats, land degradation is a serious problem that originates from a combination of activities like deforestation, mining, shifting cultivation, and intense rainfall, causing drastic decline in crop yield (Adhikary *et al*., 2019). It was reported that only from the cultivable part of the Koraput district, Odisha, 13.3 million tonnes (Mt) of soil was lost annually at the rate of 43.9 t ha$^{-1}$yr$^{-1}$ (Naik *et al*., 2015). From a field experiment in the EGH region of Odisha, Adhikary *et al*. (2017) reported soil loss from upland paddy cultivated fields as 12.5 t ha$^{-1}$yr$^{-1}$. Mostly uplands with steep slopes are subjected to degradation.

The general topo-sequence of the EGH region of Odisha is classified into five types, locally known as *Dongar* (high slope rainfed upland), *Pada* (rainfed medium land), *Beda* (rainfed medium land surrounding the habitation), *Saria* (flat medium land surrounded by two *Jhola* systems) and *Jhola* land (stream fed terraced low land) (Dash *et al*., 2017; Jakhar *et al*., 2015). The potential of land for agriculture increases from *Dongar* to *Jhola* land (Madhu *et al*., 2016). Unlike uplands which experience soil degradation and water scarcity, *Jhola* land have a favorable condition in terms of water availability for most of the year. In an earlier study, it was reported that average base flow and surface flow of *Jhola* (streams) were 37.2% and 34.7% of the total rainfall, respectively (Panda *et al*., 2011). Therefore, these lands have a high potential for agricultural development due to (a) easy access to stream water, (b) high soil fertility relative to upland, and (c) availability of soil moisture during dry seasons. Previous studies indicated the high potentiality of these lands to meet food requirement of people of Eastern Ghats region (Madhu *et al*., 2016; Panda *et al*., 2010). Hence, these lands can potentially be used for agriculture in a sustainable way. However, till date there is no information about the exact spatial extent of this land. Therefore, it is necessary to make an inventory of these lands to implement proper policy and management planning at local and regional levels. In a recent study, Adhikary *et al*. (2019) mapped the land use of Koraput district of Odisha where they have discussed about the dynamics of forest land and shifting cultivated area. But, not the area and potentiality of *Jhola* land were discussed. In the recent agricultural policy of Government of Odisha, much importance has been given to low land rice cultivation, where *Jhola* land can fit appropriately. As the cultivation practice of *Jhola* land system is mainly devoid of fertilizer use, the improved package of practices as mentioned in the policy draft can add a new dimension to paddy cultivation in *Jhola* land system.

RS coupled with GIS is an excellent, cost effective and time saving alternative technique for delineating any eco-system over a larger area in real time, compared to conventional field mapping methods (Bal *et al*., 2018; Dash *et al*., 2018a; Chowdary *et al*., 2008; EI-Kawy *et al*., 2011; Ozesmi and Bauer, 2002; Sudhishri *et al*., 2017). RS needs development of methods and datasets for rapid delineation of land surface features to map their spatial distribution. At larger spatial scales, applicability of RS techniques could vary significantly at different localized areas due to high degree of variability in the spectral signature of the associated ground feature (Adhikary *et al*., 2019). The complexities in any types of eco-systems in terms of their vegetation, soil and hydrological features themselves impose many limitations for identifying, mapping and characterization of ecosystems. Even though many limitations exist in using RS for mapping any ecosystem, still it is widely used across the world. In this study an attempt has been made to (1) identify, delineate and map the spatial extent of *Jhola* land areas using RS and GIS and (2) characterize the land for their potential use.

## 2. MATERIALS AND METHODS

### Study Area

Koraput district located in the southern part of the Odisha, India has a total geographical area of 8379 km$^2$, and lies between 81°05′04″ to 83°24′46″ East longitude and 18° 04′00″ to 19°05′00″ North latitude (Fig. 1). The district has a population of 13.8 lakh, with a population density of 157 people per km$^2$ (Census, 2011). It has 14 administrative blocks namely Bandhugaon, Boipariguda, Boriguma, Dasamantpur, Jeypore, Koraput, Kotapad, Kundra, Lamataput, Laxmipur, Nandapur, Narayanpatna, Pottangi and Semiliguda. The study area is characterized by tropical climate, having mean maximum and minimum temperatures of 35.8°C and 7.6°C, respectively (Adhikary *et al*., 2015). The average annual rainfall varies between 980 to 1843 mm, with a mean of 1452 mm occurring in 70 days (Dash *et al*., 2017). Average Potential Evapo-transpiration (PET) in the district varies from 5 mm day$^{-1}$ to 8 mm day$^{-1}$ and 160 mm month$^{-1}$ to 240 mm month$^{-1}$, highest during the month of May (238.0 mm) and lowest during the month of August (154.3 mm) (Dash *et al*., 2018b). The major geological units of the district fall under *Charnockite* and *Khondolite* group (Dash *et al*., 2018b). The soils of the study area have been identified as Alfisols and Inceptisols, and both soil depth and texture vary with the topography, and become less favourable for cultivation with increasing slope steepness (Dash *et al*., 2017). The hills and hill slopes are mostly dominated by light yellow to brown soils, whereas sandy to loamy soils are found in the foothills and upland. The net sown area is 2446.6 km$^2$, and accounts 31.6% of the area. *Pada* and *Beda* land are used for upland paddy (*Oryza sativa*), maize (*Zea mays*), little millet (*Panicum sumatranse*) and finger millet (*Eleusine coracana*) during *kharif* (rainy season), whereas niger (*Guizotia abyssinica*) and mustard are cultivated during *rabi* (winter season). *Saria* land is used for vegetable cultivation throughout the year based on availability of water. *Jhola* land is exclusively used for cultivation of paddy throughout the year.

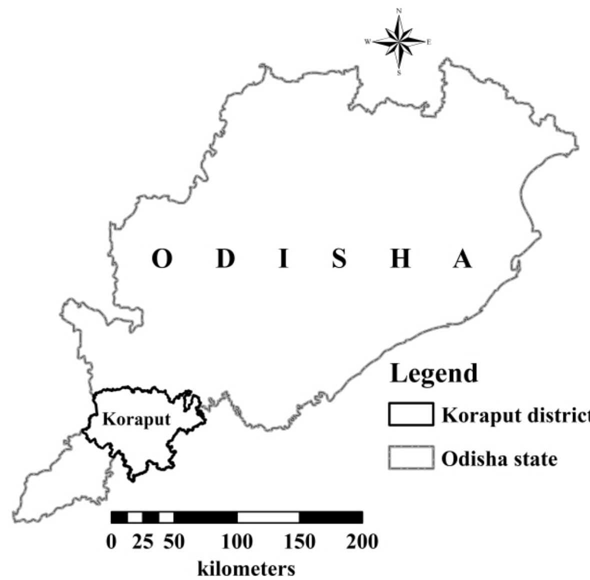

**Fig. 1. Map of study area**

### Data and Assessment Period

In this study, Survey of India (SoI) topographic sheets (scale-1:50000, year-2008), IRS-P6, Linear Imaging Self

Scanner (LISS) IV geocoded FCC of May 2013 and Advanced Space Borne Thermal Emission and Reflection Radiometer (ASTER) Digital Elevation Model (DEM, 30 m) were used for assessment of spatial extent of the *Jhola* land. The SoI topographic maps were used for preparation of base map, stream network map and ground truthing, after geo-referencing. ASTER data was also used for preparation of slope map. IRS LISS-IV images were mosaicked and analyzed for *Jhola* land assessment.

### Derivation of Stream Network, Slope, Indices, and Delineation of *Jhola* Land

The methodology used for identification of *Jhola* land is presented in Fig. 2. Supervised classification was used for identification of *Jhola* land. Also, visual interpretation along with on screen digitization was carried out from the satellite data on the basis of tone, texture, shape and association (Table 1). Data processing, extraction of information and analyses were performed using Earth Resources Digital Analysis System (ERDAS) Imagine (ERDAS, 2008), and ArcGIS 10.0 (ESRI, 2010) software packages.

*Jhola* land occurred mainly along the lower elevations in the topo-sequence, along the streams. Generally these are areas of valley bottoms along or on the stream bed. Therefore, the delineation of stream lines could be used as a better indicator for mapping *Jhola* land. Stream networks were delineated using SoI topographical sheets in ArcGIS environment. Slope determines the relative topographic position of the landscape at every point in space and thus differentiates upland from lowland. Theoretically, slope is a better indicator of topographic position than elevation (Kulawardhana *et al.*, 2007). This is because, the same elevation can be present in two different locations while one can be upland and another is lowland. In contrast, slope is always determined relative to the elevation of the surrounding pixels. As a result, lowland pixels get separated from upland pixels. In this study, slope map of the study area was developed from ASTER DEM.

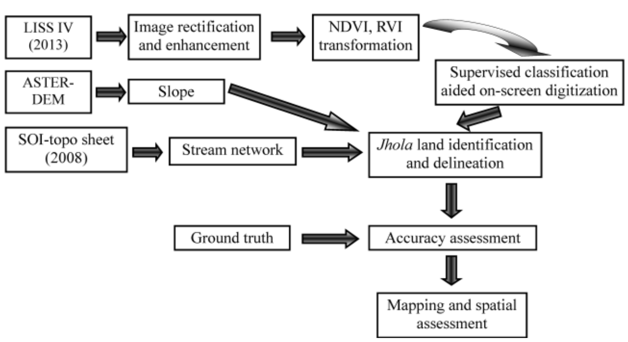


**Fig. 2. Methodology used for mapping and assessment of *Jhola* land system**

Apart from slope, two indices (i) normalized difference vegetation index (NDVI) Rouse *et al*. (1974) and (ii) ratio vegetation index (RVI) Tucker (1979) were derived from the satellite images, and their threshold values were determined. NDVI is an index which provides a measure of vegetation density and vigour. The values of NDVI can range from -1.0 to +1.0, but for vegetation, values typically range between 0.1 and 0.7. Higher index values are associated with higher levels of healthy vegetation cover, whereas clouds and snow will cause index values to be near to zero, making it appear that the vegetation is less green (Tucker, 1979). RVI distributes the near infrared (NIR) reflectance values by the visible red (R) reflectance values. This index is least influenced by soil brightness at LAI greater than three (Ghobadifar *et al*., 2014). Trial and error method was used to get the optimum value of these indices to determine maximum separability of the *Jhola* land from other land uses. Thereby, the best threshold values for delineating *Jhola* land were obtained from two different indices of LISS-IV images.

### Ground Truthing

The delineated *Jhola* land were validated through ground-truthing. Ground-truth data on spatial location, land use, soil moisture status, and topographic characteristics were collected from selected sample sites during the period from 2014-2016. A total of 300 (250 for *Jhola* land and 50 for non-*Jhola* land) points were collected for ground-truthing. Random sampling was adopted for the selection of sample sites based on the information provided by local farmers, state government officials, and on the accessibility

**Table: 1**
**Tone and texture used for visual identification of various land uses from satellite images**

| Land use | Tone | Texture | Shape | Description |
|---|---|---|---|---|
| Dense forest | Dark red | Rough | Varying | Tall dense tree with good canopy cover |
| Open forest | Light red | Medium | Varying | Sparsely covered by forest vegetation with open surface and less canopy cover |
| Scrub | Dark tan | Coarse | Irregular | Scattered stunted vegetation with exposed ground surface |
| Barren land | Whitish | Fine | Irregular | Rocky or sandy areas with sparse or no vegetation |
| Agricultural land | Light green/light pink | Smooth | Regular | Crops on the field |
| *Jhola* land | Light red/ pink/light green/ brown | Smooth | Regular | Crops on the field, and associated with stream |
| Water body | Dark/light black | Smooth | Irregular | Rivers, reservoirs, ponds |

of the sites from road-network. Spatial locations were obtained from GPS readings, and cross checked with *Google Earth* image. Percentage accuracy in mapping *Jhola* land was determined by over laying 250 *Jhola* land points, which were identified during ground-truthing, on the delineated *Jhola* land map.

## 3. RESULTS AND DISCUSSION

### Defining *Jhola* Land

The very first criterion for mapping *Jhola* land was to have a clear definition of *Jhola* land. Schedule survey, group discussions with farmers, state government officials and field visits were conducted to accomplish this. It was revealed that *Jhola* is a local term used for stream, and *Jhola* land is a modified stream bed (terraced low land), occurring on or along the stream in lower part of the topo-sequence, continuously fed with flowing water throughout the year, and extended either side for paddy cultivation using diverted stream water.

### Accuracy of *Jhola* Land Delineation

The accuracy of *Jhola* land delineation was assessed based on ground truth data. It was observed that the overall accuracy level was 0.88 with producer's accuracy, user's accuracy and kappa statistics as 0.96, 0.90 and 0.64, respectively (Table 2). The limitations of automatic classification of any land use using RS techniques is due to spectral overlapping between different land covers (EI-Kawy *et al*., 2011; Kulawardhana *et al.,* 2007; Sudhishri *et al*., 2017). However use of both spectral enhancement techniques with human interpretations during the process of screen digitization minimized the error to a great extent (Adhikary *et al*., 2019; Dash *et al*., 2018[a]; Kulawardhana *et al.,* 2007; Pelorosso *et al*., 2009). Therefore, it can be inferred that a high level of accuracy was achieved for *Jhola* land delineation using supervised classification along with on-screen digitization.

### Elevation and Slope of *Jhola* Land

The elevation map of the Koraput district is presented in Fig. 3. Elevation in the district ranges between 127 m and 1655 m. Higher elevation is prominent in the middle, eastern and southeastern parts of the district. It was observed that *Jhola* land are associated with high elevation areas, of the district, *Jhola* land systems occur mainly at or above 700 m elevation. The slope map (USDA classification) of Koraput district is shown in Fig. 4. The distribution of area under different slope group is presented in Table 3. In Koraput district, maximum area (1533.7 $km^2$) falls under slope of 15-25%, which is 18.3% of TGA of the district. Similarly, about 995.6 $km^2$ area falls under slope of 1-3%, contributes 11.9% of TGA of the district. Regarding slope of the *Jhola* land, the slope at lower part of the *Jhola* land systems varies between 2-3%, however on an average, the slope of the *Jhola* land and systems (beginning of the *Jhola* land to the end) varies from 1-10%. Panda *et al.* (2011) also reported that average slope of the lower part of *Jhola* land systems varied between 1.2% to 2.9%. Because

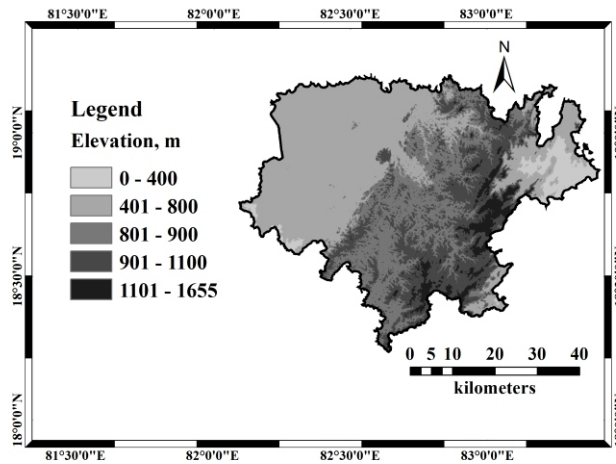


**Fig. 3. Digital elevation model of Koraput district**

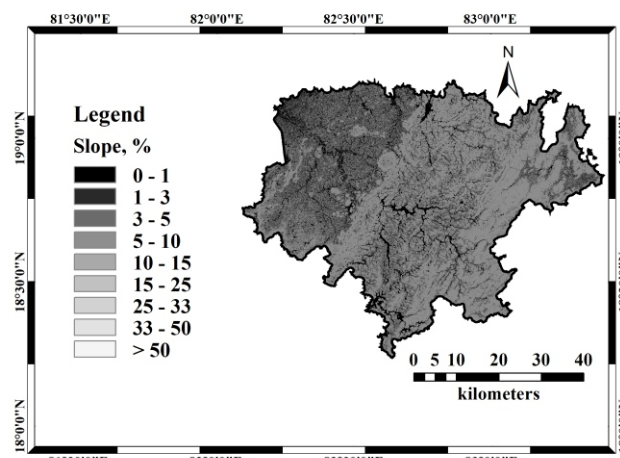


**Fig. 4. Slope map of Koraput district**

**Table: 2**
**Accuracy of *Jhola* land delineation**

| Classes | *Jhola* land | Non-*Jhola* land | Total | Producer accuracy | User accuracy |
|---|---|---|---|---|---|
| *Jhola* land | 224 | 9 | 233 | 0.96 | 0.90 |
| Non-*Jhola* land | 26 | 41 | 67 | 0.61 | 0.82 |
| Total | 250 | 50 | 300 | | |
| Over all accuracy | | | | | 0.88 |
| Kappa-statistic | | | | | 0.64 |

**Table: 3**
**Area wise distribution of Koraput district under different slope categories**

| Slope (%) | Area (km$^2$) | % of TGA | Slope (%) | Area (km$^2$) | % of TGA |
|---|---|---|---|---|---|
| 0-1 | 690.8 | 8.2 | 15-25 | 1533.7 | 18.3 |
| 1-3 | 461.1 | 5.5 | 25-33 | 850.0 | 10.1 |
| 3-5 | 534.5 | 6.4 | 33-50 | 1169.6 | 14.0 |
| 5-10 | 1347.2 | 16.1 | > 50 | 678.6 | 8.1 |
| 10-15 | 1113.5 | 13.3 | | | |

the *Jhola* land are man-made (modified terraced land), the slope of *Jhola* land are generally gentle, whereas, the slope of the adjoining land was observed to be steep.

### Relation to Stream Order

The stream network map of Koraput district is shown in Fig. 5. Kolab river having highest stream order (7$^{th}$ order), flows through the study area. By superimposing delineated *Jhola* land map on the stream network map, it was observed that majority of *Jhola* land systems originate either from 2$^{nd}$ or 3$^{rd}$ order streams that is around 84% of total *Jhola* land system (Table 4). Only 8% and 7% of *Jhola* land system originates from 1$^{st}$ and 4$^{th}$ order streams, respectively. However, no *Jhola* land system originates on 5$^{th}$ or higher order stream. This is because the water flow capacity and the base flow of the 1$^{st}$ order streams are inadequate to raise crops, and very often the stream dries up during summer season. Apart from this, most of the 1$^{st}$ order streams are surrounded by forest and dense scrub. Similarly, when the stream order increases, the flow volume and flow velocity increases simultaneously, and leaves less chance of cultivation of crops. However, 2$^{nd}$ and 3$^{rd}$ order streams are more suitable in terms of maintaining moisture content of the *Jhola* system round the year, and are having less flow velocity in comparison to higher order streams. Besides, cultivation practices are easier when the water depth and flow velocity in the fields are less. The stream order and number of *Jhola* lands under a particular order stream was related to each other with the following equation:

$$J_n = -17.25S^2 + 84.75S - 57.75 \quad \ldots(1)$$

Where, $J_n$ is the number of *Jhola* lands in a stream order and S is the stream order. Eq. 1 can be used to obtain the approximate number of *Jhola* lands of any particular stream order with upper limit of 4$^{th}$ order stream.

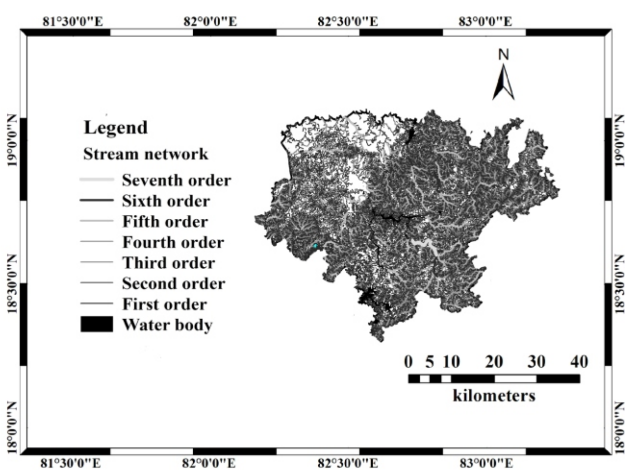


**Fig. 5. Stream network map of Koraput district**

**Table: 4**
**Percentage of *Jhola* land systems originating from different stream orders (sample based)**

| Order of the stream | % of *Jhola* land systems origin |
|---|---|
| 1$^{st}$ | 8 |
| 2$^{nd}$ | 48 |
| 3$^{rd}$ | 36 |
| 4$^{th}$ | 7 |
| 5$^{th}$ | - |

### Spatial Extent of *Jhola* Land System

The NDVI maps of all 10 blocks of the district are shown in Fig. 6. NDVI values ranged from -0.21 to 0.68 for different blocks in the study area. All the blocks have negative and positive values. This reflects the image has the water bodies that have negative value as well as greenness that have positive value. The best NDVI for delineating *Jhola* land was observed to be vary between -0.08 to 0.43 (Table 5). Lower NDVI values indicated *Jhola* land in fallow condition, as the satellite image was for the month of May. This was because many of the *Jhola* land were not cultivated during the summer season due to inadequate moisture in the *Jhola* land, and if cultivated, some of them were harvested by month of May. When *Jhola* land have paddy, the NDVI values may vary depending on vegetation density and vigor. Higher NDVI values indicated the vegetation (paddy) at maturity stage. The NDVI has been widely used indicator for distinguishing one land use from other (Huang *et al*., 2013; Li *et al*., 1998; Reddy and Reddy, 2013). Our results also agreed with similar studies reported by researchers (Guan *et al*., 2016; Nayak, 2006). It was observed that in general, RVI values ranged from 0.01 to 5.2 for different blocks, however RVI values for *Jhola* land was 0.4 (Table 5). Block wise *Jhola* land occurrence in Koraput district is presented in Table 6. Among 14 blocks of Koraput district, *Jhola* lands are present in 10 blocks, and absent in 4 blocks namely, Bandhugaon, Boipariguda, Kundra, and Kotapad. Maximum *Jhola* land occurs in Dasamantapur

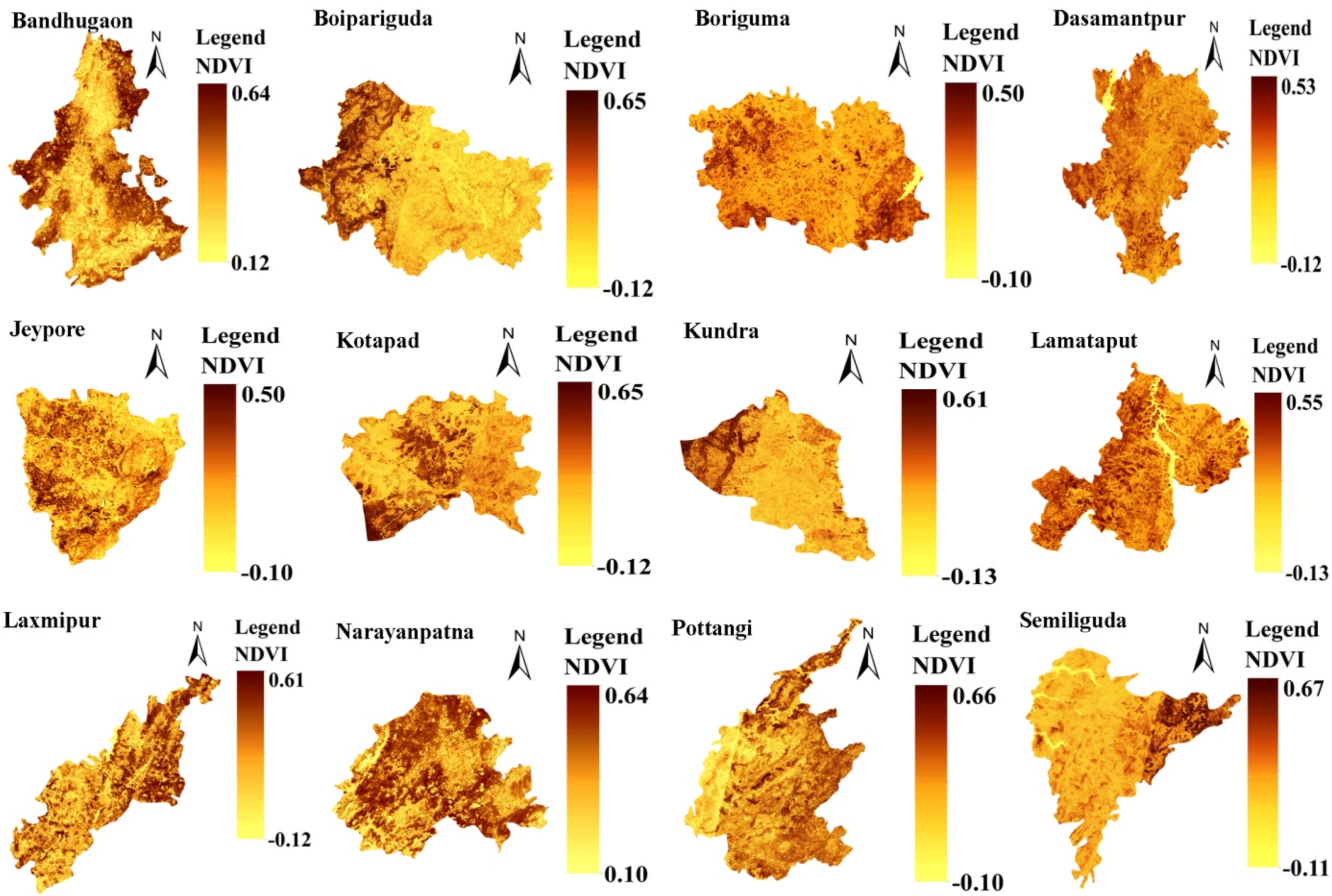


**Fig. 6. NDVI images of different blocks of Koraput district**

**Table: 5**
**Indices and their threshold values for *Jhola* land delineation**

| Index/parameter | Definition | Range | Threshold value (Best delineated *Jhola* land) |
|---|---|---|---|
| Slope | Percentage slope derived using spatial analyst tools available in Arc GIS | 0 to 100% | 1-5% |
| NDVI | NDVI = $\rho_3$-$\rho_2$/$\rho_3$+$\rho_2$ $\rho_2$ and $\rho_3$ are the reflectance values derived from the bands 2 (Red) and 3 (Near Infra Red) of LISS-IV image, respectively. | -1 to +1 | -0.08 to 0.43 |
| RVI | RVI = $\rho_3$/$\rho_2$ $\rho_2$ and $\rho_3$ are the reflectance values of the Red and Near Infra Red bands of LISS-IV image, respectively. | 0 to 5.2 | 0.4 |

**Table: 6**
**Areal extent of *Jhola* land system in different blocks of Koraput district**

| Block name | Area ($km^2$) | % area |
|---|---|---|
| Boriguma | 3.1 | 0.5 |
| Dasamantpur | 38.9 | 4.2 |
| Jeypore | 3.8 | 0.8 |
| Koraput | 16.5 | 2.9 |
| Lamataput | 21.7 | 3.6 |
| Laxmipur | 10.8 | 2.1 |
| Nandapur | 32.6 | 4.5 |
| Narayanpatna | 12.1 | 2.3 |
| Pottangi | 19.3 | 3.6 |
| Semiliguda | 27.9 | 5.2 |

block (38.9 $km^2$), which is about 4.2% of TGA of the district, followed by Nandapur and Semiliguda. Block wise *Jhola* land maps are presented in Fig. 7. In Koraput district, area under *Jhola* land is found to be 186.7 $km^2$, which is 2.2% of the TGA of the district.

## Catchment Characteristics of *Jhola* Land

Randomly some of the *Jhola* land systems were selected to know the dominant catchment characteristics of the *Jhola* land, which has been represented in Table 7. Mainly three types of land uses, such as mixed or dense forest, open or dense scrub and agricultural areas, are major land uses present in the catchment area of the *Jhola* land systems. The proportions of different land uses vary with

**Table: 7**
**Catchment characteristics of *Jhola* land systems**

| Representative villages | Block name | Dominating land use of catchment | *Jhola* land (ha) | Catchment area (ha) | Agriculture area (%) | Area under scrub (%) | Area under forest (%) | Catchment elevation (m) | *Jhola* land elevation (m) | Slope (%) | Area : length ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Amati Ambaguda | Dasamantapur | Agriculture, dense scrub, | 34.55 | 481.4 | 39.1 | 60.9 | 0.0 | 880-1340 | 880-980 | 2.6 | 1.26 |
| Ankadaeli | Lamataput | Agriculture, dense scrub, mixed forest | 6.42 | 211.0 | 16.9 | 78.5 | 4.6 | 845-1060 | 842-893 | 2.4 | 1.41 |
| Badigada | Lamataput | Agriculture, mixed forest, scrub | 22.50 | 279.3 | 45.6 | 20.2 | 34.1 | 835-1872 | 845-878 | 1.4 | 1.21 |
| Budapanasa | Narayanpatna | Agriculture, mixed dense forest | 7.23 | 68.5 | 14.1 | 0.0 | 85.9 | 850-1058 | 880-920 | 4.1 | 0.81 |
| Chapra | Koraput | Agriculture, mixed forest, scrub | 38.50 | 478.2 | 75.3 | 13.4 | 11.4 | 860-980 | 860-920 | 1.5 | 1.20 |
| Doliguda | Lamataput | Agriculture, mixed forest | 11.20 | 223.7 | 84.3 | 1.4 | 14.3 | 860-900 | 847-873 | 1.3 | 1.14 |
| Dumuripadar | Laxmipur | Agriculture, scrub | 5.75 | 79.4 | 31.9 | 68.1 | 0.0 | 880-1200 | 895-960 | 4.9 | 0.76 |
| Ichhapur | Narayanpatna | Agriculture, mixed dense forest | 5.69 | 103.1 | 7.6 | 0.0 | 92.4 | 910-1180 | 910-1010 | 4.8 | 0.51 |
| Jholajhanjar | Lamataput | Agriculture, dense scrub, dense mixed forest | 105.00 | 1428.5 | 52.5 | 30.5 | 17.0 | 835-1060 | 834-924 | 1.2 | 1.93 |
| Kargasatbeda | Narayanpatna | Agriculture, dense scrub | 18.64 | 156.9 | 21.9 | 78.1 | 0.0 | 870-1280 | 890-1020 | 4.8 | 0.60 |
| Lohaba | Nandapur | Agriculture, scrub | 28.00 | 325.9 | 75.8 | 24.2 | 0.0 | 870-1040 | 870-920 | 2.5 | 1.64 |
| Malitala | Dasamantapur | Agriculture, dense scrub | 44.00 | 927.5 | 70.6 | 29.4 | 0.0 | 860-1140 | 860-960 | 1.7 | 1.55 |
| Mohanapada | Koraput | Agriculture, dense scrub | 31.48 | 576.1 | 70.3 | 29.7 | 0.0 | 860-1040 | 860-940 | 2.6 | 1.85 |
| Nimalpada | Pottangi | Agriculture, dense scrub, mixed forest | 7.82 | 199.2 | 63.6 | 35.7 | 0.6 | 840-1200 | 840-880 | 2.9 | 1.48 |
| Pakjhola | Semiliguda | Agriculture, dense scrub | 97.00 | 1103.0 | 59.3 | 40.7 | 0.0 | 880-1320 | 880-980 | 1.8 | 2.02 |
| Podapdar | Pottangi | Agriculture, dense scrub, mixed forest, | 18.21 | 350.8 | 87.1 | 12.9 | 0.0 | 940-1160 | 940-980 | 1.5 | 1.34 |
| Sisaguda | Pottangi | Agriculture, dense scrub | 14.16 | 267.4 | 71.0 | 29.0 | 0.0 | 900-1120 | 900-980 | 3.4 | 1.12 |
| Sukuguda | Koraput | Agriculture, scrub, mixed forest, | 15.38 | 240.7 | 82.9 | 11.0 | 6.1 | 860-1020 | 860-900 | 1.9 | 1.13 |
| Tushba | Lamataput | Agriculture, scrub | 4.54 | 209.5 | 84.3 | 15.7 | 0.0 | 850-983 | 863-885 | 1.3 | 1.27 |

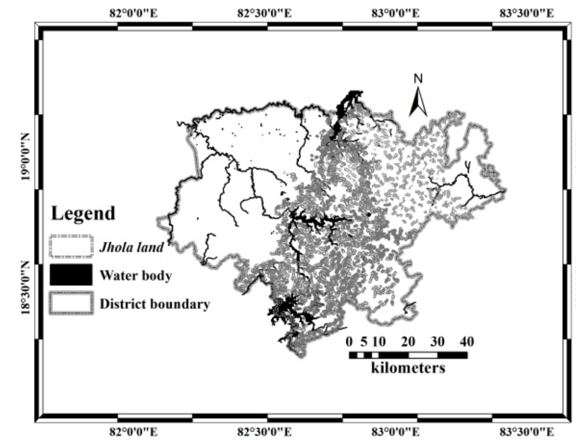


**Fig. 7. *Jhola* land and map of Koraput district**

**Table: 8**
**Classification of *Jhola* land systems**

| Criteria | Class | Description |
|---|---|---|
| Based on size | Very small | Area of *Jhola* land less than 1 ha |
| | Small | Area of *Jhola* land varies between 1-2 ha |
| | Medium | Area of *Jhola* land varies between 2-10 ha |
| | Large | Area of *Jhola* land varies between 10-50 ha |
| | Very large | Area of *Jhola* land more than 50 ha |
| Slope | Level | Slope varies between 1 to 3% |
| | Gentle | Slope varies between 3 to 5% |
| | Moderate | Slope varies between 5 to 10% |
| Pereniality | Perennial | Cultivated throughout the year |
| | Partial | Upper reach of the *Jhola* land perennial systems remain fallow during winter season, and middle and lower reaches cultivated round the year |
| | Seasonal | Only cultivated during rainy season |

different *Jhola* systems. In almost all the *Jhola* systems, agricultural land uses are present, however in some of the *Jhola* systems, either forest or scrub land uses are present. The percent of agricultural land uses in different *Jhola* systems varies from 7.6% to 87.1% of total catchment area. Similarly for scrub and forest land uses, the contributions of these land uses are 1.4% to 78.5%, and 0.6% to 92.4% of total catchment area, respectively. In all the cases, the maximum elevation of *Jhola* land systems origin is lower than that of catchment area. The area to length ratio of *Jhola* land systems ranged from 0.51 to 2.02.

## Classification of *Jhola* Land

The *Jhola* land has been classified based on three categories; a) size b) slope, and c) pereniality (Table 8). Based on size, *Jhola* land were classified as very small (<1 ha), small (1-2 ha), medium (2-10 ha), large (10-50 ha) and very large (>50 ha). The number of different sizes of *Jhola* land present in different blocks of Koraput district is presented in Table 9. It was observed that the area of maximum number of *Jhola* land systems varied between 2-10 ha and which are coming under medium size. According to slope, *Jhola* land has been classified as land having slope 1-3%, 3-5%, and 5-10%. According to pereniality, *Jhola* land can be classified as perennial (cultivated throughout the year due to good moisture condition), partially perennial (upper reach of the *Jhola* land systems remain fallow during winter season, and middle and lower reaches are cultivated throughout the year), and seasonal (only cultivated during rainy season). It was observed that 34% of *Jhola* lands are perennial, 45% partially perennial, and 21% of *Jhola* lands are seasonal.

## 4. CONCLUSIONS

In EGH region of Odisha, paddy constitutes a significant component of major food staples and is cultivated across a range of agro-ecosystem, including upland and low land, irrigated and rainfed landscapes. However, low land paddy cultivation is practiced mostly in the valleys of the hilly tracts, locally known as *Jhola* land, which is a terraced stream bed occurring on or along the lower order streams. Unlike uplands which experience water scarcity, *Jhola* lands have a favorable moisture status which supports cultivation of paddy throughout the year. In Koraput district, 187.6 $km^2$ area is under *Jhola* land systems, having mono-crop of paddy, covering 10 blocks of the district. These *Jhola* land systems occur at elevation of 700 m or more above the mean sea level, and $2^{nd}$ and $3^{rd}$ order streams mostly contribute origin of the *Jhola* land systems.

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**Table: 9**
**Block wise number of *Jhola* land systems under different size groups**

| Block | Very small (< 1 ha) | Small (1-2 ha) | Medium (2-10 ha) | Large (10-50 ha) | Very large (> 50 ha) |
|---|---|---|---|---|---|
| Boriguma | 10 | 12 | 24 | 8 | 0 |
| Dasamantpur | 16 | 28 | 105 | 118 | 28 |
| Jeypore | 15 | 13 | 49 | 11 | 0 |
| Koraput | 19 | 44 | 123 | 35 | 6 |
| Lamataput | 3 | 6 | 52 | 41 | 17 |
| Laxmipur | 12 | 21 | 62 | 47 | 12 |
| Nandapur | 16 | 24 | 70 | 56 | 8 |
| Narayanpatna | 10 | 23 | 81 | 21 | 17 |
| Pottangi | 8 | 22 | 59 | 72 | 12 |
| Semiliguda | 35 | 35 | 83 | 50 | 9 |
| Total | 144 | 228 | 708 | 459 | 109 |

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