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एफ एन ए, एफ एन ए एस सी, एफ एन ए ए एस
सचिव एवं महानिदेशक

TRILOCHAN MOHAPATRA, Ph.D.
FNA, FNASc, FNAAS
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# Foreword

The Eastern Ghats lie parallel to the East Coast of the Peninsular India between $11^{0}$ 30' to $21^{0}$ 0' N latitude, and $77^{0}$ 22' to $85^{0}$ 20' E longitude. It comprises of disjoined hill ranges with impoverished flora and fauna as the area is well distributed by the excellent drainage, climatic disturbances like cyclones, past geological changes including the transgression of Bay of Bengal, and as more so by human settlement during the ages and their agricultural practices. The Eastern Ghats High Land (EGHLR) Region of Odisha covers an area of 1.25 M ha spreading over two districts of Odisha and supports about 2.13 million populations. Majority of the population predominantly tribal is dependent on agriculture and land-based activities. The agricultural production system in the area is mostly rain-fed and mono-cropped.

The general topo-sequence of EGHLR of Odisha especially Koraput is classified in to five types, locally known as *Dongar Pada, Beda, Saria* and *Jhola* land. The potential of land for agriculture or farming, decreases upwards from *Jhola* land to *Donger*. The *Jhola* land are the land which occur overwhelming along the lower order streams or the upper reaches of river systems mainly cultivated with paddy throughout the year. *Jhola* land have high potential for agricultural development in comparison to adjacent upland, because of water availability throughout the year. Since *Jhola* land are highly productive, it is being felt that assessment of *Jhola* land along with formulation of government policies to protect and sustain the productivity of this land is necessary. The objectives of this technical bulletin is to assess the spatial extent of *Jhola* land areas in Koraput district, Odisha using Remote Sensing and Geographical Information Systems, to characterize *Jhola* land with respect to soil, geology and its resource use efficiency.

I am glad that ICAR-Indian Institute of Soil & Water Conservation (IISWC), Research Centre, Sunabeda, Koraput drawing upon the earlier work carried out by the researchers of the Centre, along with output of an institutional project entitled "*Mapping and Characterization of Jhola land areas in Koraput District*", has prepared a technical bulletin. I am sure that the document will be useful to farmers, researcher and policy makers of the Koraput district of Odisha in undertaking the issues, evolving suitable strategies needed to mitigate the problems of *Jhola* land agriculture, and its efficient utilization for sustainable production.

**(Trilochan Mohapatra)**

Healthy Soils for a Healthy Life

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**Dr P. R. Ojasvi**
Acting Director

# Foreword

Koraput district is one among the tribal dominated district of Odisha in Eastern Ghats region having agriculture and land based activities as the mainstay of rural economy. Paddy constitutes a major component of staple food and is cultivated across a range of agro-ecosystem, including upland, lowland, irrigated and rain-fed landscapes occupying 55% of total cultivated land. Lowland paddy cultivation is practiced mostly in the valleys of the hilly tracts, locally known as *Jhola* land. These land systems are modified stream beds found on or along the stream, and have a favorable hydrological condition for paddy cultivation throughout the year. Since *Jhola* land are highly productive, it is being felt that assessment of spatial extent of *Jhola* land in the Koraput district, along with formulation of government policies to protect and sustain the productivity of this land is necessary.

Hitherto such tribal knowledge was not known to mainstream agricultural development. For the first time, ICAR-IISWC present the document entitled "Characterization and development of *Jhola* land systems of tribal's of Koraput district, Odisha: Status and Strategies" which focusses on quantification and characterization of *Jhola* land in the district using modern tools.

I convey my congratulations to all the authors for their hard work in bringing out this technical bulletin. I am sure this publication will be helpful for the policy planners, researchers, natural resource managers and farmers for getting insight of *Jhola* land production systems in Eastern Ghats High Land region.

**P.R. Ojasvi**

# Acknowledgements

The technical bulletin is an outcome of the ICAR-IISWC approved Research project on "*Mapping and characterization of Jhola land areas in Koraput district*". Data were also use from two other research projects of the IISWC, Research Centre, Koraput as well as data provided by Odisha Watershed Development Mission, Bhubaneswar.

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**Authors**

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# Executive Summary

In this study, delineation, charact-erization of the *Jhola* land along with estimation of resource use efficiency of *Jhola* land in Koraput district, Odisha have been carried out using remote sensing and geographical information system. The DEM, slope, stream network, and geological maps for Koraput district have been prepared, and these maps were used as a base map for identification of *Jhola* systems. Digital data of the IRS Resourcesat (P6) LISS IV geocoded FCC of 2013 has been used for assessment of area under *Jhola* land in the district. The supervised classification along with visual interpretation of satellite images have been adopted for identification of *Jhola* land. The *Jhola* land areas have been delineated from their grey red tone, scattered pattern, and association with streams. Necessary field checks have been carried out and corrections made at required places by using google earth image. Selection of *Jhola* land ground-truth points was based on the information provided by local farmers, state government officials, and on the accessibility of the sites from road-network. Data on agricultural land use, soil moisture status and topographic characteristics were also recorded based on visual observations. Percentage accuracy of mapping *Jhola* land was determined by over laying a total number of 250 *Jhola* land points which were identified during the ground truth on the delineated *Jhola* land map. Further soil and water samples have been collected from *Jhola* land and analyzed for their characterization. Surface geology of the selected *Jhola* land also studied. From the collected secondary data, resource use efficiency of *Jhola* systems has been estimated.

In this study, from field visits, discussion with farmers, line departments, analysis of satellite images, google earth images, it was found that *Jhola* land occurred in 10 blocks of Koraput district. This land is associated with high elevation areas. Elevation in the district ranges between 127 and 1655 m above msl. However, *Jhola* Land systems occur at or above 700 m elevation. The best NDVI for delineating *Jhola* land areas was observed to be varied between -0.08 to 0.43. Among 14 blocks of Koraput district, *Jhola* land was absent in 4 blocks namely, Bandhugaon, Boipariguda, Kundra, and Kotapad. Maximum *Jhola* land present in Dasamantapur block (38.9 sq. km), which is about 4.2% of the TGA of the district, followed by Nandapur and Semiliguda. In Koraput district, total area under *Jhola* land is found to be 186.7 sq. km, which is 2.2% of TGA of the district. Majority of *Jhola* land systems originate either from 2$^{nd}$ or 3$^{rd}$ order streams, which is around 84% of total *Jhola* land systems. Only 8% and 7% of *Jhola* land systems originate from 4$^{th}$ and 1$^{st}$ order streams respectively. However no *Jhola* land systems originate on 5$^{th}$ or higher order stream. Regarding slope of the *Jhola* systems, the maximum slope is up to 5%, with variation ranges 1.2 to 4.9%. The area to length ratio of *Jhola* systems ranges 0.51 to 2.02.

In Koraput district, major geological unit are khondalite group, charnockite group, bengal group, chhattisgarh group and igneous intrusive. Major lithology in *Jhola* land dominated area is acid charnockite and khondalite schist, which occupies about 61.89% of TGA of the district, and comes under Eastern Ghats super group. The organic carbon content of *Jhola* land soils ranged from 0.7 to 1.1 % in the surface soils (0-20 cm) and 0.7 to 1.0 % in the sub-surface soils (20-40 cm) with mean and standard deviation values of 0.9 and 0.11%; and 0.9 and 0.12%, respectively with very low variation between the soils of different *Jhola* sites, therefore, the soils of the study area can be categorized as medium to high in terms of OC where as soil fertility status of *Jhola* systems indicated low to medium N content. Water quality of the *Jhola* system indicated that it is suitable for irrigation.

Total energy inputs required for cultivation of paddy in *Jhola* land has been grouped into internal (direct) and external (indirect) energy inputs. Internal energy inputs are animal and labour inputs, where as fertilizers, chemicals and seeds are considered as an external energy inputs. Total internal (direct) energy input is about 5324.3 MJ/ha which is 62.5% of the total energy inputs against only 37.5% of the total energy inputs from external (Indirect) energy inputs (3189.3 MJ/ha). Global warming potential (GWP) of paddy under *Jhola* has estimated from the internal and external inputs used in the production system. The estimated GWP of rice cultivation under low input *Jhola* production system is 610.8 kg $CO_2$ Equivalent/ha. It has been observed that 65% of the GWP is from internal inputs and remaining 35% of GWP is contributed from the external inputs like inorganic fertilizers, chemicals and seeds. The low GWP attributed to low external inputs in the rice production system. Though, *Jhola* land is considered to be one of the most fertile arable lands in Koraput district, Odisha, however the sustainability of these systems depends on protection of catchment area.

# 1. Introduction

## 1.1 Background

The Eastern Ghats along the Peninsular India is extending over 1750 km with average width of about 100 km and located between $11^0$ 30' to $21^0$ 0' N latitude, and $77^0$ 22' to $85^0$20' E longitude. The hilly area from the river Mahanandi to the river Godavari covering districts of Odisha namely Boudh, Gajapati, Ganjam, Kalahandi, Kandhamal, Khordha, Koraput, Malakangiri, Nayagarh, and Rayagarh and Andhra Pradesh districts of East Godavari, Srikakulam, Visakhapatnam, Vizianagaram, and West Godavari represents the Northern Eastern Ghats. Eastern Ghats High Land Region (EGHLR) of Odisha falls under Agro-Ecological Zone No. 12 (Ahlawat, 2009); covers an area of 1.25 M ha spreading over two districts of Odisha and supports about 2.13 million populations (Census, 2011). This region is characterized with diverse natural resources, human resources and the socio-economic aspects (Sharda, 2013). Majority of the population predominantly tribal is dependent on agriculture, animal husbandry and land-based activities.

However, this region of Odisha is gradually facing problems of heavy soil erosion, loss of soil fertility and deforestation, which is causing acute environmental degradation and severe ecological imbalance (Lenka et al., 2012; Adhikary et al., 2017). The agricultural production system in the area is mostly rain-fed and mono-cropped. Shifting cultivation or slash and burn agriculture, locally known as "*Podu chasa*", still exists as one of the main forms of agriculture in this region. Shifting cultivation in its more traditional and cultural integrated form, is an ecological and economically viable system of agriculture as long as population density is low and cycles are long enough to maintain soil fertility (Anon, 1992). However, with changing requirements of high population pressure on land, shifting cultivation becomes very devastating and causing drastic decline in crop yield, loss of forest wealth, soil fertility, biodiversity and environmental degradation (Roder et al., 1997; Ranjan and Upadhay, 1999; Tripathy et al., 2015). It was observed that, only from the cultivable part of the Koraput district of EGHLR of Odisha, 13,333 thousand tonnes of soil was lost annually at the rate of 43.9 t/ha/y (Naik et al., 2015). Naik et al. (2015) also reported that cropping sequences like finger millet-fallow-fallow, paddy-fallow-fallow and niger-fallow-fallow contributed 20.4%, 19.9% and 14.5% of total soil loss, respectively, from Koraput district. Madhu et al. (2016) reported the potential soil loss of Koraput district was 25-30 t/ha/y. In a field experiment in EGHLR of Odisha, Adhikary et al. (2017) found the soil loss from upland paddy cultivated fields as 12.5 t/ha/y. Due to shortening of cultivation cycle, quite often, the secondary forests also do not get adequate time to regenerate. The repeated use of land with short shifting cultivation cycle finally converts the shifting cultivated fallows into degraded wasteland. The burgeoning population along with the changing climatic condition is putting pressure on the available agricultural land for fulfilling the demand of the people, where shifting cultivation can't be considered as a sustainable way of mitigating the food demand. In this context, another topo-sequence in the EGHLR of Odisha, locally known as *Jhola* land, can be considered as an alternative.

The general topographic feature of EGHLR of Odisha especially Koraput is classified in to five types, locally known as *Dongar* (high slope rainfed up land), *Pada* (*rainfed* medium land), *Beda* (*rainfed* medium land surrounding the habitation), *Saria* (flat medium land surrounded by two stream) and *Jhola* land (stream fed terraced low land) (Fig 1.1). The characteristics of each land type is described in Table 1.1. *Donger* is the upper slope of the hills, and *Jhola* is the stream at lower side of slope. *Pada* and *Beda* are used for upland paddy and ragi cultivation, where as *Saria* used for vegetable cultivation. The potential of land for agriculture decreases upwards from *Jhola* land to *Donger*. *Jhola* land is the land which occurs along the lower order streams or the upper reaches of river systems (Panda et al., 2011), mainly cultivated with paddy. This land

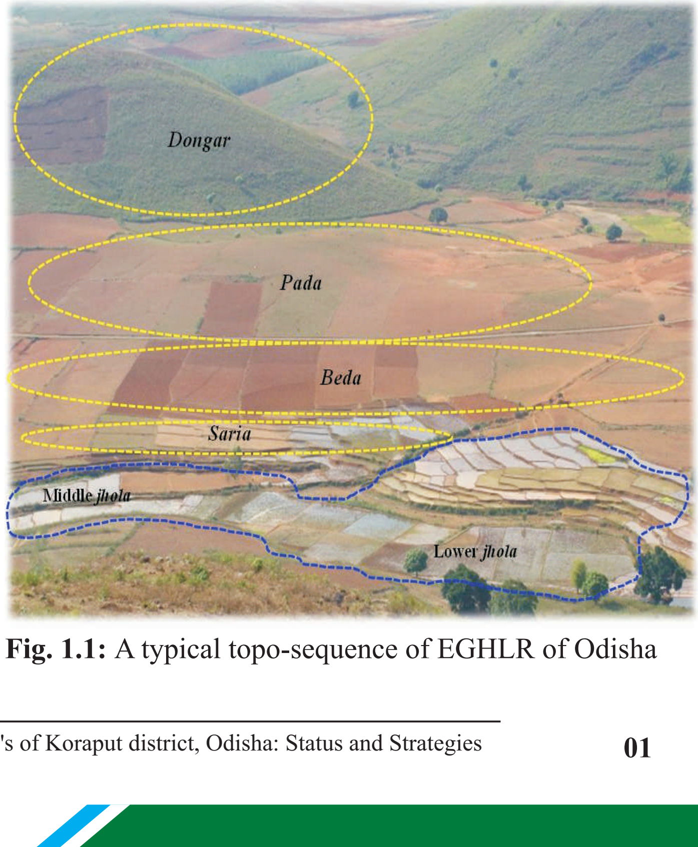



**Fig. 1.1:** A typical topo-sequence of EGHLR of Odisha

comprises the watersheds of drainage axes in which seepage and runoff from adjacent upland converge. Unlike upland which experience water scarcity, *Jhola* land have a favorable hydrological condition that ensures that water is at, or near, the surface for most of the year. The mean base flow and surface flow were observed to be 42% and 35% of the total rainfall, respectively for *Jhola* of Kokriguda watershed, whereas for *Jhola* of Chullapari watershed, same was observed as 33% and 37%, respectively (Panda et al., 2011). Therefore, this land systems have a high potential for agricultural development due to a number of reasons including: (a) easy access to stream water, (b) high soil fertility relative to upland, (c) soil moisture availability during dry seasons and (d) mixed farming system with aquaculture practices. Previous studies indicated the high potentiality of these land to meet the self sufficiency of the tribal peoples of this Eastern Ghats region (Panda et al., 2010). Hence, *Jhola* land systems can potentially be used for agriculture in a sustainable way and have a high potential for increasing food production, compared with adjacent upland, where the degradation of the soil is occurring. It is therefore necessary to make an inventory of these land systems.

In general, for detecting, quantifying and mapping of any land use, conventional technique such as ground survey is used, however, for regional studies, these techniques are either cost effective or time consuming. Modern technologies and tools such as remote sensing coupled with Geographical Information Systems (GIS) offer an excellent alternative to conventional techniques in monitoring and assessing the extent of any land use/cover in real time because of its digital format, suitable for computer processing, and accurate geo-referencing procedures (Chowdary et al., 2008; El-Kawy et al., 2011). This has become more promising particularly in hilly rugged terrains where the ground survey is expensive and cumbersome to carry out.

Paddy being the major crop cultivated in the *Jhola* land almost throughout the year season by season from time immortal, this landform is subjected to intensive cultivation. There is a need of paying attention for sustainable production through scientific management of soil. Further, it is observed that sediments brought down from the hills by flood during monsoon and partially deposited in these valley land which are supposed to alter the physical, chemical properties and nutrient status of the *Jhola* land soils (Patnaik et al., 2004; Panda et al., 2010, Panda et al., 2011). Available information to date suggests that the physical and chemical properties of *Jhola* land have not been studied extensively, probably because of its good hydrological status, high physical complexity and heterogeneity. Therefore not only the knowledge about the spatial extent of *Jhola* land, but also characterization of their soil physical and chemical properties are useful in overcoming the problem of ecological imbalance for sustainable development of agriculture in this region, so as to wean away the tribal farmers from the shifting cultivation to settled agriculture. In this context, this technical bulletin is dealing with the rapid, reliable assessment, delineation and characterization of the *Jhola* land in Koraput district of Odisha using modern tools and techniques, which are presented in subsequent chapters.

## 1.2 Objectives of the Study

- To assess the spatial extent of *Jhola* land areas in Koraput district.
- To characterize the *Jhola* land systems in terms of water and nutrient availability.
- To quantify the resource use efficiency of *Jhola* land systems.

**Table 1.1:** General transect in Eastern Ghats high land region

| Particulars | *Donger* | *Padda* | *Beda* | *Saria* | *Jhola land* |
|---|---|---|---|---|---|
| Altitude (m) | 1200-1500 | 900-1200 | 900-1000 | 800-1000 | 750-950 |
| Slope (%) | > 100 | 70-80 | 10-12 | 5-8 | 1-5 |
| Land use | Scrub, forest | Shifting cultivation | Upland cultivation | Vegetables | Low land cultivation |
| Water availability | Rainfed, high runoff | Rainfed, high runoff | Water scarcity in lean period | Water scarcity in lean period | Perennial water |
| Problems | Land degradation, shifting cultivation, high erosion | High runoff, gully erosion | Low productivity, open grazing | High soil loss, poor water management | Flooding in monsoon, bund breaching |
| Production potential | Silvi-pasture | Horticulture with grasses | Agro-forestry, farm pond, agri-horti system | Conservation agronomy | Intensive agriculture |

# 2. Description of Study Area

## 2.1 Location

Koraput district located in the southern part of the Odisha state has a total geographical area (TGA) of 8379 sq. km. It lies between 81° 05'04" to 83° 24' 46" East longitude and 18°4'00" to 19° 5' 00" North latitude (Fig. 2.1). It is bordering on the north by Nawarangpur, Kalahandi and Rayagada districts of Odisha, Andhra Pradesh in the south and east and Chattishgarh in the west. The district is divided into 14 community development blocks namely Bandhugaon, Boipariguda, Boriguma, Dasamantpur, Jeypore, Koraput, Kotapad, Kundra, Lamataput, Laxmipur, Nandapur, Narayanpatna, Pottangi and Semiliguda. In terms of geographical area Boipariguda block having almost 14% of TGA the district followed by Semiliguda (13% of TGA) and Boriguma (9% of TGA) and lowest area in Narayanpatna block (2% of TGA). As reported by Census (2011), the district has a population of 13.8 lakhs which accounts 3.3% of total state population and stands 15th in terms of population in the state. In the district, 57% population is under Scheduled Tribes (ST) and 14% is under Scheduled Caste (SC). Population density of Koraput district during 2011 is 157 people per sq. km, where as in 2001, it was 134 people per sq. km. and about 84% of the population lives in rural areas.

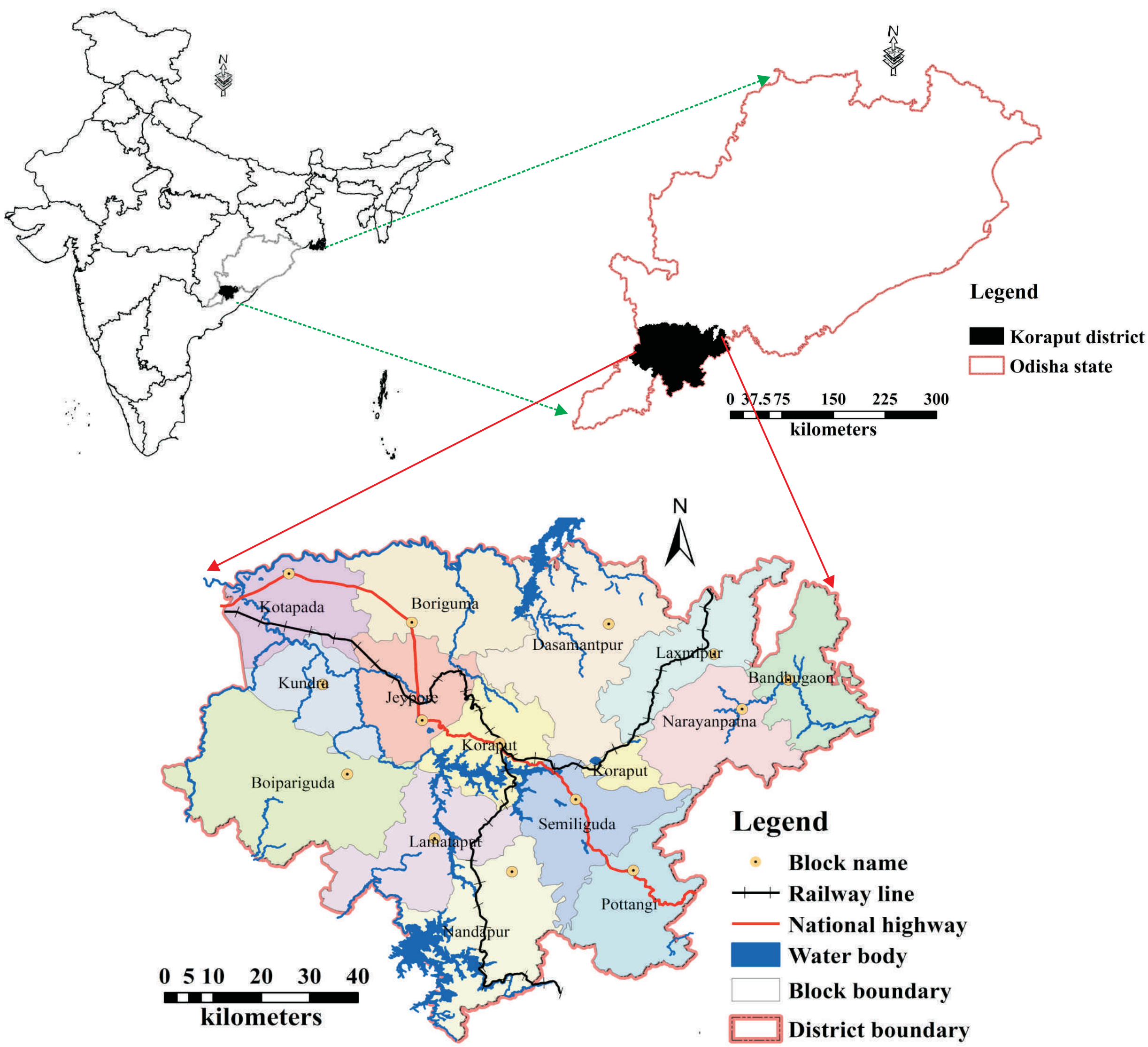



**Fig. 2.1:** Administrative map of Koraput district

## 2.2 Climate

The district is characterized by tropical climate with hot summer, cold winter and rainy seasons. The study area experiences mean maximum and minimum temperatures of 35.8°C and 7.6°C, respectively (Adhikary et al., 2015). The summer season commences from March and continues till middle of June. During summer, the mean daily maximum temperature remains around 40°C while the mean daily minimum temperature is around 14°C. The winter season generally starts from November and continues up to the end of February. The temperature in winter drops below 1°C at some places of the study area, otherwise it is in the range of 10°C to 13.5°C. The south-west monsoon season starts in the second week of June and continues up to mid of October. The spatial variability of annual rainfall is presented in Fig 2.2. The average annual rainfall varies between 980 to 1843 mm, having mean rainfall of 1452 mm occurring in 70 days (Fig. 2.3). Less rainfall occurs in north-east part of the area, where as highest rainfall occurs in south-west part of the study area. The north-east monsoon gives erratic and insufficient rainfall. Annual erosive rainfall accounts for about 75% of the total annual rainfall in the study area. The wettest months are July (332.5 mm) and August (311.0 mm), whereas the driest ones are December (4.4 mm), January (8.0 mm) and February (11.6 mm) (Fig. 2.4). However, the area experiences a special monsoon feature characterizing intense and short duration storms, helps in generating enormous runoff and heavy soil loss (Lenka et al., 2012; Adhikary et al., 2015). Average potential evapo-transpiration (PET) in the district varies from 5 to 8 mm per day and 160 to 240 mm per month (Fig 2.4), highest during the month of May (238.0 mm) and lowest during the month of August (154.3 mm).

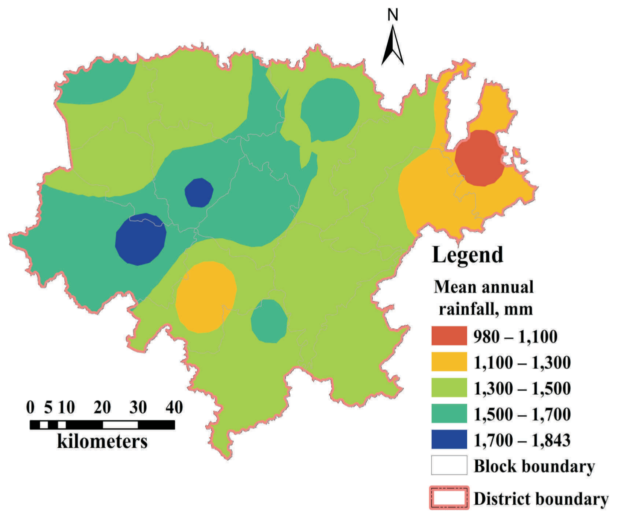



**Fig. 2.2 :** Mean annual rainfall in Koraput district

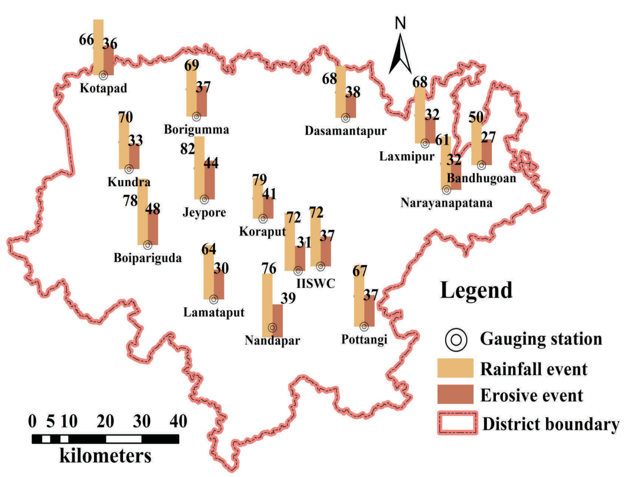



**Fig. 2.3 :** Block wise mean rainfall and erosive rainfall events in Koraput district

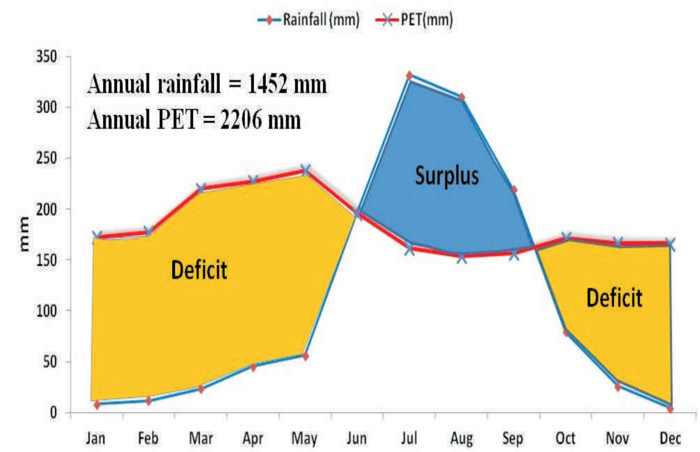



**Fig. 2.4 :** Monthly rainfall and PET in Koraput district

## 2.3 Land Use and Land Cover

Land use refers to the human activity that is associated with a specific land-unit, in terms of utilization, impacts, or management practices (Jansen and Di Gregorio, 2002; Comber, 2008). Land use is, therefore, based upon function, where a specific use can be defined in terms of a series of activities undertaken to produce one or more goods or services (Jansen and Di Gregorio, 2002). Physiographically, except the north-western and west-west central part, almost the entire district is occupied by forest, highly rugged mountain, interspersed with narrow inter-montane valleys. The land use map of Koraput district (year-2013) is presented in Fig. 2.5 and details of area and percentage of area under different land use is given in Table 2.1. The land

**Table 2.1:** Land use pattern in Koraput district

| Land use | Area (sq. km) | Area (%) |
|---|---|---|
| Water body | 201.7 | 2.4 |
| Scrub | 1127.6 | 13.5 |
| Open forest | 1193.8 | 14.2 |
| Dense forest | 964.7 | 11.5 |
| Barren land | 1588.6 | 19.0 |
| Shifting cultivated area | 206.7 | 2.5 |
| Agricultural land | 2646.6 | 31.6 |
| Miscellaneous | 449.3 | 5.4 |

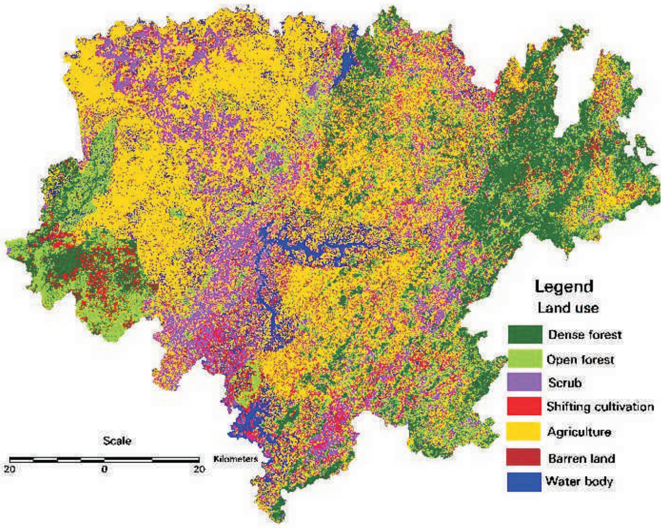



**Fig. 2.5:** Land use map of Koraput district

utilization pattern indicates that out of total area, the forest area constitute 2158.5 sq. km, which is about 25.8% of the TGA of the district. The net sown area is 2446.6 sq. km, and accounts 31.6% of the TGA. Though the tribal farmers of the district gradually shifting to settled agriculture from shifting cultivation, however, shifting cultivation is still practiced in some places, which accounts nearly 2.5% of TGA of the district**.** Scrubs including both open and dense scrub comprise 13.5 % of the TGA of the district.

## 2.4 Geology and Geomorphology

Major parts of the Koraput district are underlain by hard-rocks of Pre-Cambrian age. The consolidated rocks of upper to middle Proterozoic age occupy a small portion of north-western part of the district. The recent to sub-recent alluvium occurs as thin and discontinuous patches along the prominent drainage channel. The Laterite occurs as capping over the country rocks in isolated pockets. The generalized stratigraphic sequence in the district is given below:

| | | |
|---|---|---|
| Recent to sub recent | | Alluvium, Laterite |
| Upper to middle Proterozoic | Chhattisgarh Group | Purple shale, Limestone, Basal quartzite |
| Proterozoic to Archaean B | Bengal Group | Quartzite, Quartz and Biotite gneiss |
| | Eastern Ghats Group | Biotite bearing garnetiferous granite. Gneiss with mega-crystal of white feldspar. |
| Archaean | | Garnet-sillimanite schist, Green khondalite Quartzite and calc-granulite. |

In Koraput district, major geological unit are khondalite group (33.51% of TGA), charnockite group (28.38% of TGA), bengal group (27.41% of TGA), chhattisgarh group (10.36% of TGA) and igneous intrusive (0.20% of TGA). Major lithology of the district are khondalite schist (32.35% of TGA), acid charnockite (28.33% of TGA), and porphyroblastic granite gneiss (26.47% of TGA).

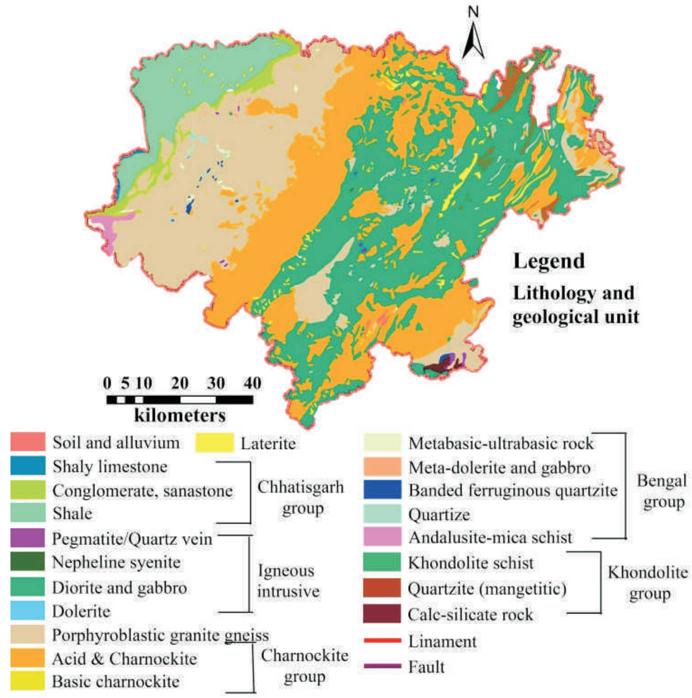



**Fig. 2.6 :** Geology map of Koraput district

The major geological units of the district fall under charnockite and khondolite-group (Fig. 2.6). Where the major geomorphic units of the district are classified as - flood plain, mesa/butte, denudational hills, pediment, deeply weathered pediplain, inselberg, structural hills, severely dissected plateau, intermontane valley, structural valley, residual hill and bazada.

## 2.5 Soil and Drainage

Major soil type found in Koraput district is matured red and lateritic soil *(Alfisols)*, mixed grey soil *(Inceptisols)* and unaltered soils with coarse parent materials *(Entisols)*. (Fig. 2.7) *Alfisols* include red loamy and red sandy soils and are generally light textured with a pH ranging from 6.5 to

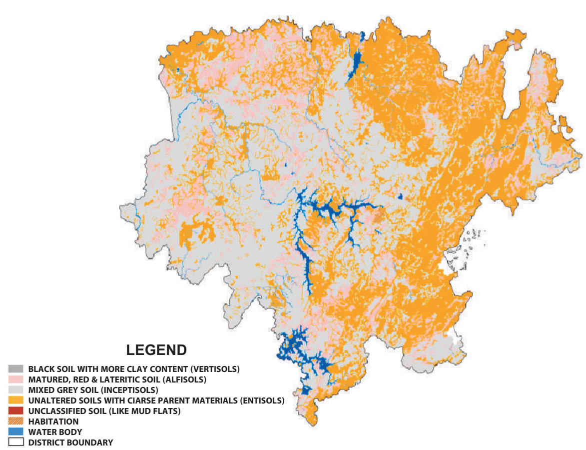



**Fig. 2.7 :** Soil map of Koraput district

7.3. Soils have average to good fertility status. *Ultisols* occur as narrow and elongated patch in the central part of the district are slightly acidic in nature with a pH ranging from 4.5 to 6.0. Block wise soil type is presented in Table 2.2.

The drainage pattern in the district is controlled by Indravati, Sabari (Kolab), Sileru, Vegavati, Subarnamukhi, Janhavati and their tributaries. The river Indravati and Kolab drains the major parts of Koraput district. Most of the tributaries of Kolab and Indravati rivers are perennial in nature. East-west flowing Indravati and north-south flowing Sabari river pass through the northern and western border of Koraput district. South east-north west flowing Kolab river traverses through the central part of the district. The rivers in general exhibit dendritic drainage pattern and are effluent in nature.

**Table 2.2 :** Block wise soil type in Koraput district*

| Block | Soil Types | Area under different slope group (ha) | | | |
|---|---|---|---|---|---|
| | | 0-3 % | 3-8 % | 8-25 % | >25% |
| Semiliguda | Matured, red and lateritic soils *(Alfisols)* | 1581.11 | 3997.20 | 1947.04 | 0.44 |
| | Mixed grey soil *(Inceptisols)* | 3219.85 | 8807.23 | 9270.85 | 64.18 |
| | Unaltered soils with coarse parent materials *(Entisols)* | 2994.28 | 4540.23 | 15646.16 | 1044.89 |
| | **Total** | **7795.25** | **17344.65** | **26864.05** | **1109.50** |
| Pottangi | Matured, red and lateritic soil *(Alfisols)* | 483.12 | 2687.75 | 4001.90 | 41.36 |
| | Mixed grey soil *(Inceptisols)* | 335.10 | 2588.45 | 12251.85 | 1205.21 |
| | Unaltered soils with coarse parent materials *(Entisols)* | 912.76 | 3975.69 | 25947.49 | 1396.81 |
| | **Total** | **1730.98** | **9251.89** | **42201.24** | **2643.38** |
| Narayanapatna | Matured, red and lateritic soil *(Alfisols)* | 1025.37 | 2374.10 | 2432.34 | 41.13 |
| | Mixed grey soil *(Inceptisols)* | 691.91 | 1880.85 | 5442.81 | 751.06 |
| | Unaltered soils with coarse parent materials *(Entisols)* | 1386.11 | 3682.13 | 28328.20 | 5246.08 |
| | **Total** | **3103.39** | **7937.08** | **36203.35** | **6038.27** |
| Nandapur | Matured, red and lateritic soil *(Alfisols)* | 3350.55 | 7820.68 | 5756.00 | 13.66 |
| | Mixed grey soil *(Inceptisols)* | 2692.57 | 7474.62 | 15628.48 | 118.20 |
| | Unaltered soils with coarse parent materials *(Entisols)* | 2093.69 | 5220.06 | 17133.06 | 525.85 |
| | **Total** | **8136.82** | **20515.36** | **38517.54** | **657.71** |
| Lamptaput | Matured, red and lateritic soil *(Alfisols)* | 1390.32 | 3912.98 | 1367.40 | 0.00 |
| | Mixed grey soil *(Inceptisols)* | 4855.90 | 12785.66 | 22713.62 | 195.84 |
| | Unaltered soils with coarse parent materials *(Entisols)* | 1567.81 | 5206.81 | 5200.34 | 0.00 |
| | **Total** | **7814.03** | **21905.44** | **29281.36** | **195.84** |
| Laxmipur | Matured, red and lateritic soil *(Alfisols)* | 974.76 | 4826.24 | 3562.53 | 90.94 |
| | Mixed grey soil *(Inceptisols)* | 669.24 | 3902.19 | 6257.66 | 358.09 |
| | Unaltered soils with coarse parent materials *(Entisols)* | 1104.74 | 6063.82 | 22147.20 | 1970.58 |
| | **Total** | **2748.74** | **14792.24** | **31967.39** | **2419.60** |
| Kundra | Matured, red and lateritic soil *(Alfisols)* | 2265.50 | 1136.68 | 134.04 | 0 |
| | Mixed grey soil *(Inceptisols)* | 14923.85 | 7904.91 | 3880.77 | 15.42 |
| | Unaltered soils with coarse parent materials *(Entisols)* | 6213.54 | 1655.29 | 107.46 | 0 |
| | **Total** | **23402.89** | **10696.88** | **4122.26** | **15.42** |
| Koraput | Matured, red and lateritic soil *(Alfisols)* | 822.68 | 2247.79 | 1478.80 | |
| | Mixed grey soil *(Inceptisols)* | 3215.87 | 12528.43 | 16937.03 | 179.63 |
| | Unaltered soils with coarse parent materials *(Entisols)* | 1447.11 | 4844.02 | 7676.17 | 721.08 |
| | **Total** | **5485.67** | **19620.23** | **26092.00** | **900.70** |

*Adopted from Orissa Space Application Centre (ORSAC), Bhubaneswar

## 2.6 Socio-Economic Status

Koraput district is a tribal dominated district having total population of 1,379,647 of which male and female were 678,809 and 700,838 respectively (Table 2.3) (Census, 2011). It accounts about 3.3% of total population of Odisha. In the district, 56.5% populations are under ST and nearly 14.0% are SC. In Koraput district 95.6% population lives in rural areas. Average literacy rate of Koraput is 49.2%

compared to 35.7% of 2001. With regards to sex ratio in Koraput, it stands 1045 per 1000 male, which is much higher than the national average (940). Highest total population is available in Boriguma block and lowest in Narayanpatna block. Total workers are 52.7% of total population of the district. Highest total workers population is in Nandapur block (59.3%) and lowest in Koraput block (43.8%). Cultivator and agriculture labourer population is about 21.2% of total population, highest in Nandapur block (32.2%) and lowest in Koraput block (9.3%).

**Table 2.3 :** Block wise socio-demographic features in Koraput district, 2011

| Block | Population (No) | Sex ratio | SC (No) | ST (No) | Literacy rate (%) | % rural | Total workers to total population (%) | Cultivator +Agriculture labourer to total population (%) |
|---|---|---|---|---|---|---|---|---|
| Bandhugaon | 58974 | 1072 | 4673 | 47059 | 27.5 | 100 | 51.3 | 17.6 |
| Boipariguda | 110746 | 1046 | 14717 | 65842 | 29.4 | 100 | 52.7 | 18.5 |
| Boriguma | 153128 | 1031 | 22772 | 77504 | 39.0 | 93.6 | 50.4 | 17.7 |
| Dasamantapur | 81693 | 1064 | 9497 | 46656 | 34.5 | 100 | 52.0 | 17.6 |
| Jeypore | 122318 | 1042 | 23753 | 58206 | 40.9 | 91.8 | 50.4 | 22.9 |
| Koraput | 74867 | 1028 | 11751 | 29472 | 47.9 | 94.7 | 43.8 | 9.3 |
| Kotpad | 94994 | 1026 | 13609 | 59748 | 37.2 | 100 | 54.3 | 17.7 |
| Kundra | 71629 | 1051 | 12209 | 36638 | 37.1 | 100 | 54.3 | 19.5 |
| Lamtaput | 66621 | 1047 | 9656 | 46745 | 35.6 | 100 | 50.0 | 18.2 |
| Laxmipur | 59873 | 1049 | 11569 | 27284 | 35.1 | 100 | 58.2 | 27.6 |
| Nandapur | 91496 | 1061 | 15058 | 48056 | 33.5 | 100 | 59.3 | 32.2 |
| Narayanpatana | 43575 | 1043 | 2548 | 36772 | 30.9 | 100 | 52.4 | 21.4 |
| Pottangi | 69401 | 1037 | 4207 | 46243 | 26.9 | 100 | 54.6 | 30.3 |
| Semiliguda | 81314 | 1037 | 8856 | 41494 | 38.0 | 100 | 53.9 | 25.7 |

# 3. Assessment of Area under *Jhola* Land Systems

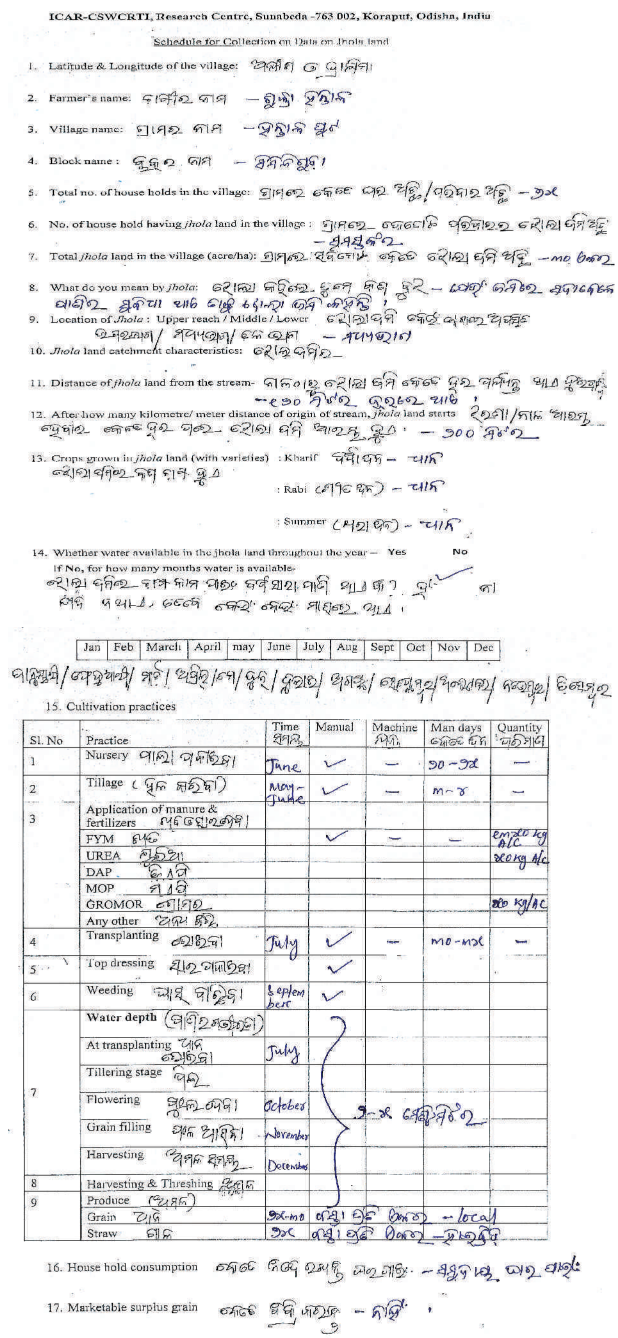
## 3.1 Delineation and Spatial Extent

The *Jhola* land ecosystem is of very high interest for agricultural development as well as for environmental conservation. The availability of water in this land form for a longer period of time as compared to the surrounding high land areas and their higher soil fertility have made the land attractive for agricultural development. With increase in population and subsequent pressure on arable land has put a question on the sustainability of the arable land. In this context, *Jhola* land can be performed many functions that are beneficial to the environment and humans, if it is used wisely and in a sustainability way. Hence, the importance of mapping and characterizing the *Jhola* land systems in order to identify and implement proper management planning at local and regional levels is needed. For precise quantification of these land, the remote sensing approach is one of the most suitable ways. Remote sensing coupled with GIS is an excellent, cost effective and time saving alternative for delineating any eco-systems over a larger area in real time, compared to conventional field mapping methods (Earth Sat, 2002; Ozesmi and Bauer, 2002; Chowdary et al., 2008; EI-Kawy et al., 2011), as it gives the consistent mapping of any land systems. Remote sensing needs development of methods and datasets for rapid delineation of land surface features to map their spatial distribution. At larger spatial scales, applicability of remote sensing techniques could vary significantly at different localized areas due to higher degree of variability in the spectral signature of the associated ground feature. 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. Thereby, the need to use accurate methods that can consistently map *Jhola* land over large areas becomes important. Given the above background, this study identifies a suitable methodology for delineating *Jhola* land in Koraput district of Odisha and the overarching goal of this study is to map, characterize, and to know the resource use efficiency of the *Jhola* land of the Koraput district, Odisha, India.

## 3.2 Definition of *Jhola* Land

The very first criteria for mapping *Jhola* land is to have a well-understood definition of *Jhola* land. For this a questioner (Fig. 3.1) was prepared and data collected from the farmers. also discussions with farmers, State government officials, and several field visits were conducted. From the study, regarding the definition of *Jhola* land, the following conclusions are drawn.

- *Jhola* is a local name of perennial stream, commonly used in Eastern Ghats high land region of Odisha.
- *Jhola* land (Fig. 3.2) is a modified/ reclaimed stream bed, occurs on or along the stream in the lower part of the topo-sequence, continuously fed with flowing water throughout the year, and extended either side for paddy cultivation using diverted *Jhola* water.


ICAR-CSWCRTI, Research Centre, Sunabeda -763 002, Koraput, Odisha, India

Schedule for Collection on Data on Jhola land

1. Latitude & Longitude of the village:
2. Farmer's name:
3. Village name:
4. Block name:
5. Total no. of house holds in the village:
6. No. of house hold having *jhola* land in the village:
7. Total *jhola* land in the village (acre/ha):
8. What do you mean by *jhola*:
9. Location of *Jhola*: Upper reach / Middle / Lower
10. *Jhola* land catchment characteristics:
11. Distance of *jhola* land from the stream-
12. After how many kilometre/ meter distance of origin of stream, *jhola* land starts
13. Crops grown in *jhola* land (with varieties) : Kharif
: Rabi
: Summer
14. Whether water available in the jhola land throughout the year – Yes No
If No, for how many months water is available-

| Jan | Feb | March | April | may | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|

15. Cultivation practices

| Sl. No | Practice | Time | Manual | Machine | Man days | Quantity |
|---|---|---|---|---|---|---|
| 1 | Nursery | June | ✓ | – | | – |
| 2 | Tillage | May-June | ✓ | – | | – |
| 3 | Application of manure & fertilizers | | | | | |
| | FYM | | ✓ | – | – | |
| | UREA | | | | | |
| | DAP | | | | | |
| | MOP | | | | | |
| | GROMOR | | | | | |
| | Any other | | | | | |
| 4 | Transplanting | July | ✓ | – | | – |
| 5 | Top dressing | | ✓ | | | |
| 6 | Weeding | September | ✓ | | | |
| 7 | Water depth | | | | | |
| | At transplanting | July | | | | |
| | Tillering stage | | | | | |
| | Flowering | October | | | | |
| | Grain filling | November | | | | |
| | Harvesting | December | | | | |
| 8 | Harvesting & Threshing | | | | | |
| 9 | Produce | | | | | |
| | Grain | | | | | |
| | Straw | | | | | |

16. House hold consumption
17. Marketable surplus grain

**Fig. 3.1:** Questioner prepared for collection of *Jhola* land data

**Fig. 3.2:** View of *Jhola* land in Koraput district

## 3.3 Types and Spatial Extent of *Jhola* Land Systems

### 3.3.1 Data Used

The Survey of India (SOI) topographical sheets (1:50,000 scale, year 2008), Indian Remote Sensing Satellites, IRS Resourcesat (P6), Linear Imaging Self Scanner (LISS) IV geocoded FCC of 2013 and Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) 30 m were the primary data sources used in this study for assessment of spatial extent of *Jhola* land. SOI-topographical sheets covering the whole Koraput district procured from SOI, Bhubaneswar, Odisha. IRS LISS-IV imageries for the year 2013 were procured from National Remote Sensing Agency (NRSA), Hyderabad.

ASTER data has global coverage, available free, well calibrated and processed (http://glcfapp.umiacs. umd.edu). The methodology used for identification of *Jhola* land systems is presented in Fig. 3.3.The supervised classification was used for identification of *Jhola* land. Also visual interpretation was carried out from the satellite data on the basis of tone, texture, shape and association (Table 3.1). The *Jhola* land areas were delineated from their grey red tone, continuous pattern, and association with streams. Necessary field checks were carried out and corrections were made at required places. Erdas Imagine 9.2 was used for image processing along with ArcGIS 10.0

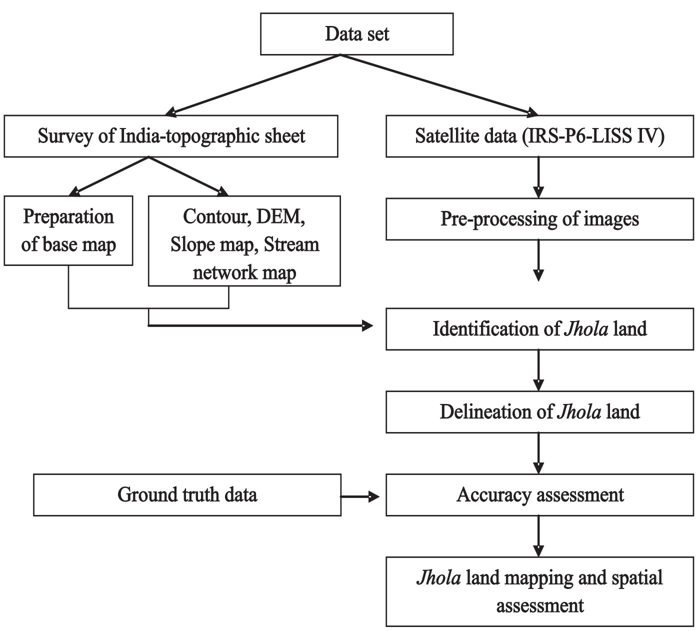



**Fig. 3.3 :** Methodology used for assessment of *Jhola* land

### 3.3.2 Drainage Network Derived from ASTER DEM Data and SOI-Topo Sheets

*Jhola* land are occurred mainly along the lower elevations in the landscape, along the stream flow paths or drainage systems. Generally these are areas of valley bottom along or on the stream beds. Therefore the delineation of stream lines could be used as a better indication for mapping *Jhola* land as that are associated with the valley bottom. Drainage network was delineated using spatial analyst tools in ArcGIS software. It involved a step-by-step procedure in which flow direction, flow accumulation, and stream network are derived in respective order. The DEM data was first subjected to correction by filling up the sinks using the tool 'fill' in ArcGIS environment, which ensures that water will flow over the DEM without any stagnation. The 'Flow Direction' and 'Flow Accumulation' tools were used in respective order and these two layers were then used to generate the stream network. While generating the stream network different threshold levels were applied to get a satisfactory level of accuracy of stream network delineation. Threshold is the minimum number of pixels that is considered to constitute a drainage link. The best threshold levels were selected through visual interpretations made on the derived stream network overlays on DEM data. Apart from using the DEM data for stream network delineation, stream networks were digitized from the SOI-topo sheets (Fig. 3.4). By comparing the stream networks derived from these two sources, it was obtained that stream network derived from SOI-toposheets are more representative than the DEM-derived stream networks.

**Table 3.1 :** Tone and texture of various land uses

| 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 |

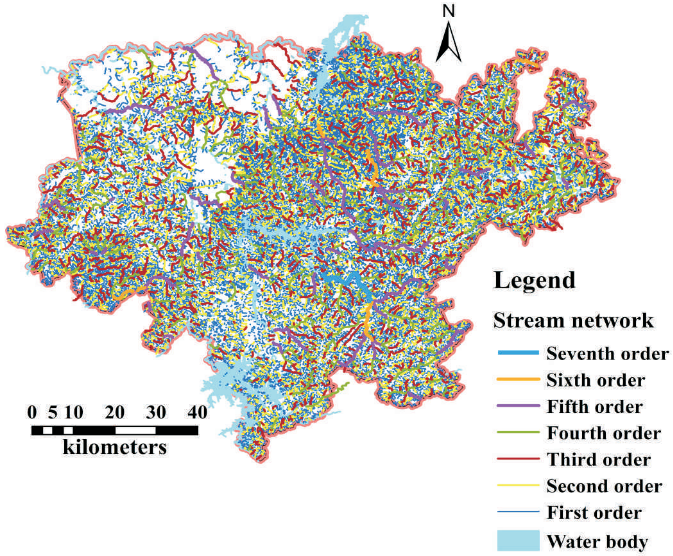



**Fig. 3.4 :** Stream network map of Koraput district

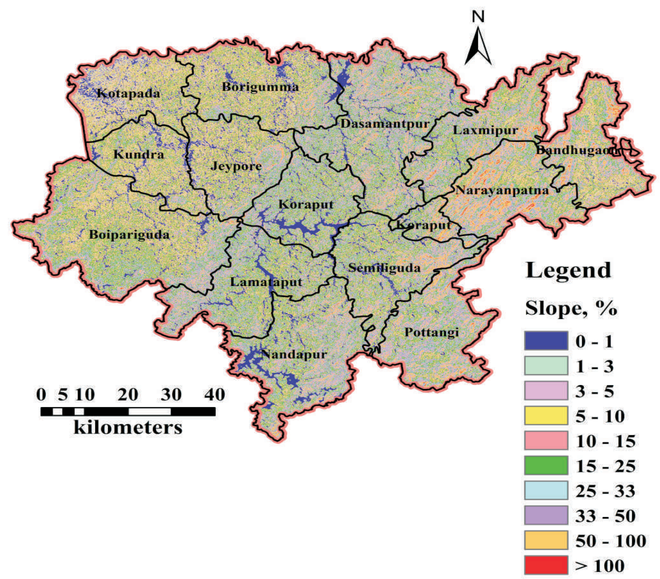



**Fig. 3.5 :** Slope map of Koraput district

### 3.3.3 Slope Derived from ASTER DEM Data

Slope determines the relative topographic position of the landscape at every point in space; thus determining upland from lowland. Theoretically, slope is a better indicator of topographic position than elevation. 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. The slope map of Koraput district is shown in Fig. 3.5, and distribution of area under different slope group is presented in Table 3.2.

**Table 3.2 :** Distribution of Koraput district under different slope

| Slope (%) | Area (sq. km) | % of TGA | Slope (%) | Area (sq. km) | % 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 | 50 100 | 666.3 | 8.0 |
| 10-15 | 1113.5 | 13.3 | >100 | 213.0 | 0.1 |

In the Koraput district, maximum area (1533.7 sq. km) falls under slope of 15-25%, which is 18.3% of total geographical area of the district.

### 3.3.4 Indices Derived from IRS LISS IV

Three indices namely Normalized Difference Vegetation Index (NDVI), RVI (Ratio Vegetation Index), Green Ratio (GR) were derived from the LISS-IV images and their threshold values presented in Table 3.3. 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 units.

**Table 3.3 :** Indices and their threshold values for *Jhola* land delineation

| Index | 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 (Rouse et al., 1974) | NDVI=ρ3-ρ2/ ρ3+ρ2 ρ2 and ρ3 are the reflectance values derived from the red band and near infra red of LISS - IV image respectively. | 1 to +1 | -0.08 to 0.43 |
| RVI (Tucker, 1979) | RVI=ρ3/ρ2 ρ2 and ρ3 are the red band and +near infra red band of IRS-LISS - IV image respectively. | 0 to 5.2 | 0.4 |
| GR (Lo, 1986) | GR=ρ3/ρ1 ρ1 and ρ3 are the green band and near infrared band of IRS-LISS-IV image respectively | 0 to 4 | 0.5 to 0.8 |

### 3.3.5 Accuracy of *Jhola* Land Delineation

*Jhola* land first delineated using the methods described in the above section prior to the ground-truthing. Ground-truth data on spatial location, land cover, soil moisture status, and topographic characteristics were collected from selected sample sites during the period from 2014-2016. A total of 250 points were collected for ground truthing. Random sampling was adopted for the selection of sample sites. Selectin of *Jhola* land ground-truth points is based on the information provided by local farmers, state government officials, and on the accessibility of the sites from road-network. Spatial locations were obtained from GPS readings. Data on agricultural land use, soil moisture status and hydro-geomorphic characteristics were also recorded based on visual observations. Percentage accuracy of mapping *Jhola* land was determined by over laying a total number of 250 *Jhola* land points which were identified during the ground truth on the delineated *Jhola* land map.

### 3.3.6 Spatial Extent of *Jhola* Land

In this study, from field visits, discussion with farmers, line departments officials, analysis of satellite images, google earth images, it was found that *Jhola* land present in 10 blocks of Koraput district (Boriguma, Dasamantapur, Jeypore, Koraput, Lamataput, Laxmipur, Nandapur, Narayanpatna, Pottangi and Semiliguda). The view of a representative *Jhola* system on google earth and on the LISS-IV image is presented in Fig. 3.6. The *Jhola* land is associated with high elevation areas. Elevation in the district ranges between 127 and 1655 m. However, *Jhola* systems occur at or above 700 m elevation. The NDVI maps of all the blocks of the district are shown in Fig. 3.7 though the NDVI values ranged -0.21 to 0.70 for different blocks in the study area, the best NDVI for delineating *Jhola* land areas was observed to be varied between -0.08 to 0.43. Similarly RVI and GR values were 0.4 and 0.5-0.8 respectively. Regarding slope of the *Jhola* land systems, the slope at the lower part of the *Jhola* land systems varies between 2-3%, however on an average, the slope of the *Jhola* land varies from 1-5%. Block wise *Jhola* land occurrence in Koraput district is presented in Table 3.4.

**Table 3.4:** Block wise *Jhola* land in Koraput district

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

Total area under *Jhola* land 186.7 $km^2$

Among 14 blocks of Koraput district, *Jhola* land absent in 4 blocks namely, Bandhugaon, Boipariguda, Kundra, and Kotapad. Maximum *Jhola* land present in Dasamantapur block (38.9 sq. km), which is about 4.2% of the total geographical area of the district, followed by Nandapur and Semiliguda. Block wise *Jhola* land maps are presented in Fig 3.8. In Koraput district, area under *Jhola* land is found to be 186.7 sq. km, which is 2.2% of the total geographical area of the district.

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 systems (Table 3.5). Only 8% and 7% of *Jhola* land systems originate from 4$^{th}$ and 1$^{st}$ order streams respectively. However no *Jhola* land systems originate on 5$^{th}$ or higher order stream. This is because; the water flow capacity of the 1$^{st}$ order stream is inadequate to raise crops. Similarly, when the stream order increases, the flow volume and flow velocity increases simultaneously, thereby leaving less chance of cultivation. However, 2$^{nd}$ and 3$^{rd}$ order streams are more suitable in terms of maintaining moisture content of the *Jhola* land systems round the year, and having less flow velocity in comparison to higher order streams.

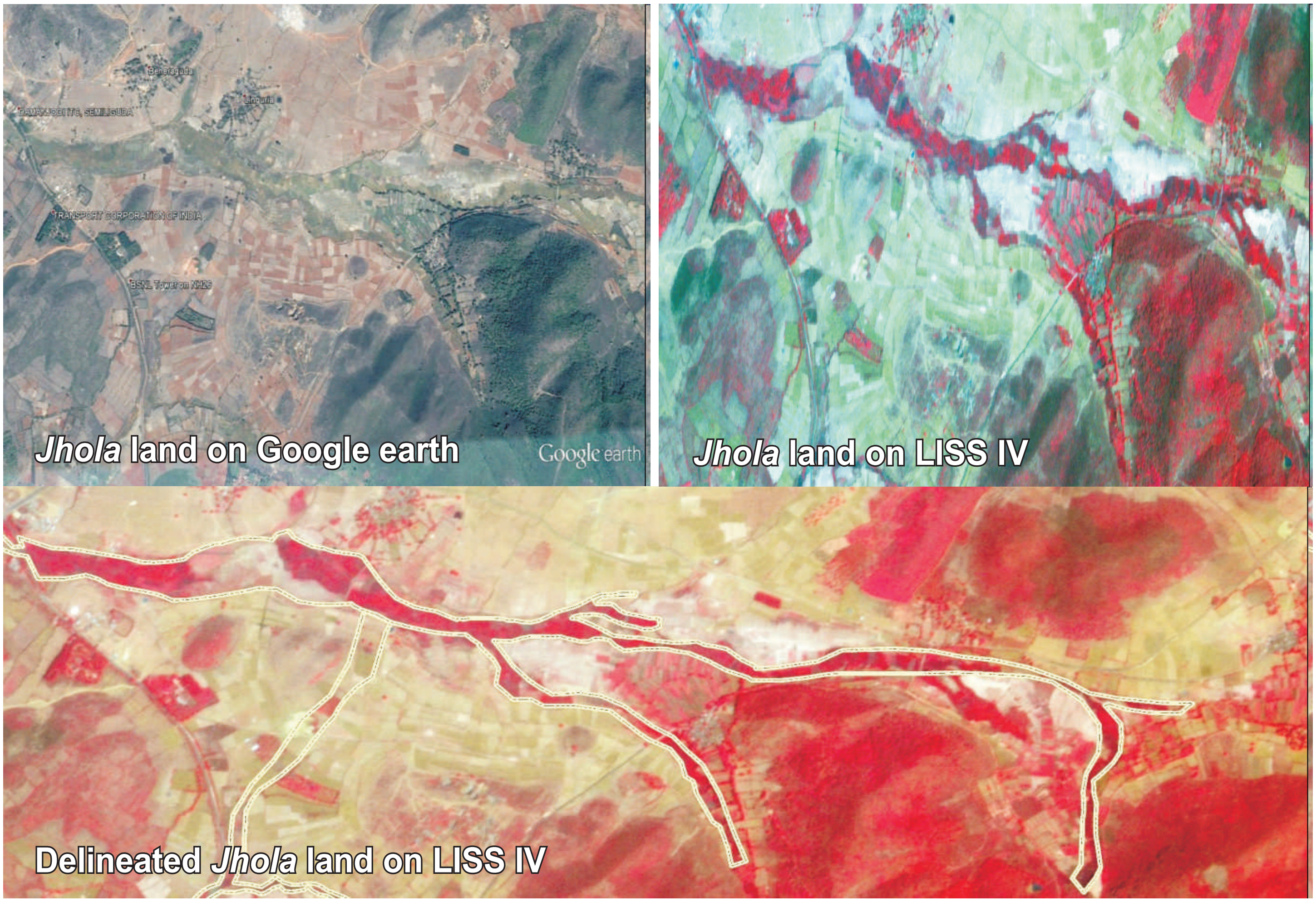



**Fig. 3.6 :** Delineated *Jhola* land on google earth and LISS IV images

**Table 3.5.** Percentage of *Jhola* land systems origin from different stream order (sample based)

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

## 3.4. Catchment Characteristics of *Jhola* systems

Randomly some of the *Jhola* systems were selected from eight blocks of the Koraput district for knowing the dominant catchment characteristics of the *Jhola* land, which has been represented in Table 3.6. It was observed that mainly three types of land uses like mixed forest or dense forest, open or dense scrub and agricultural areas were major land uses present in the catchment area of the *Jhola* land systems. The proportions of different land uses vary with different *Jhola* systems. In all most all the *Jhola* land systems, agricultural land uses present, however in some of the *Jhola* land 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 contribution 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 maximum slope of *Jhola* land systems is up to 5%, with variation ranges 1.2 to 4.9%. The area to length ratio of *Jhola* land systems range 0.51 to 2.02.

For geological study, geological maps (1:50,000 scale) were purchased from Geological Survey of India (GSI). Soil and water samples were collected from *Jhola* land systems of different blocks of Koraput district and also land holdings and productivity of *Jhola* land were collected from farmers of the study area, which will be discussed in the forthcoming chapters.

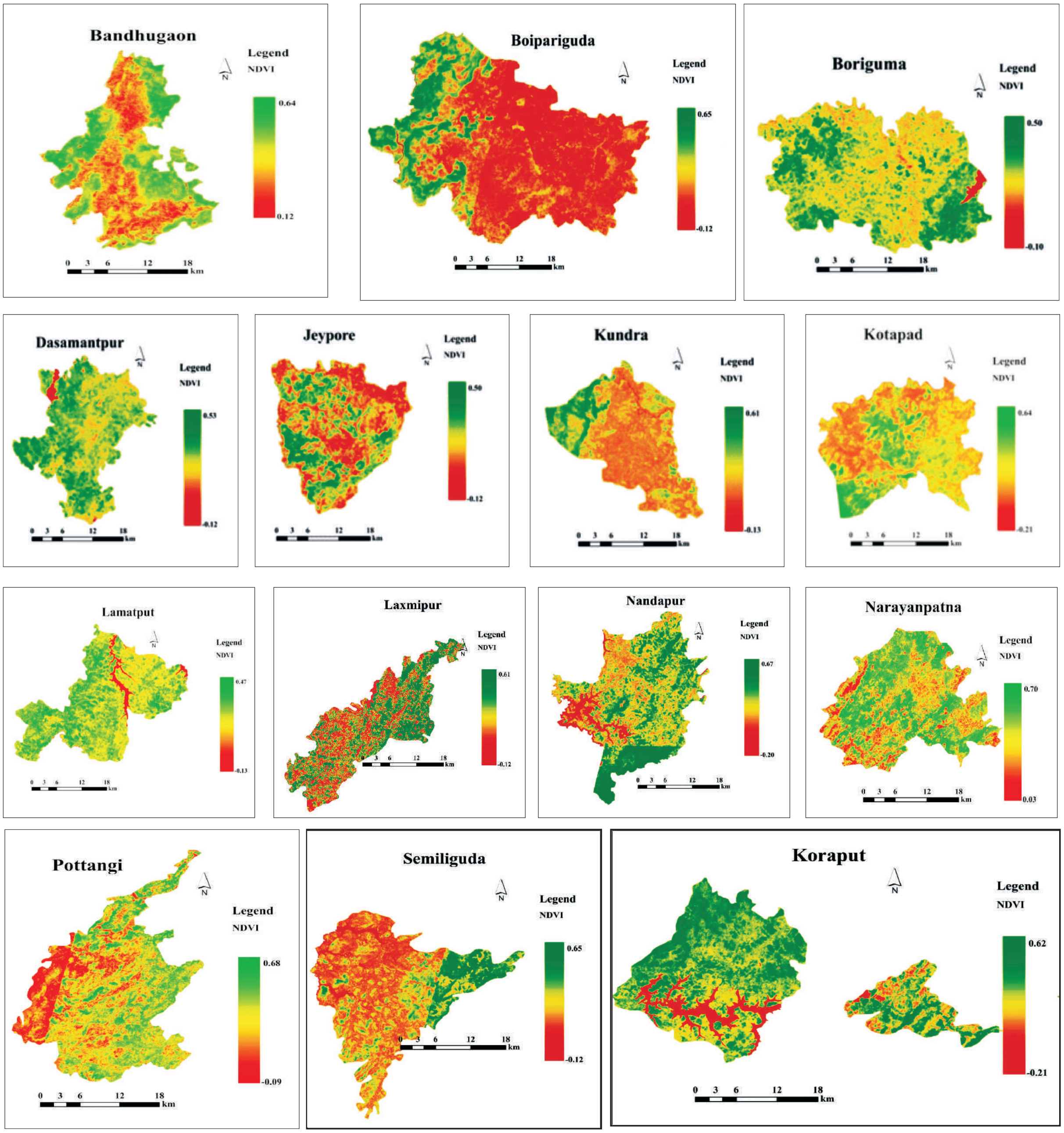



**Fig. 3.7 :** NDVI images of different blocks of Koraput district

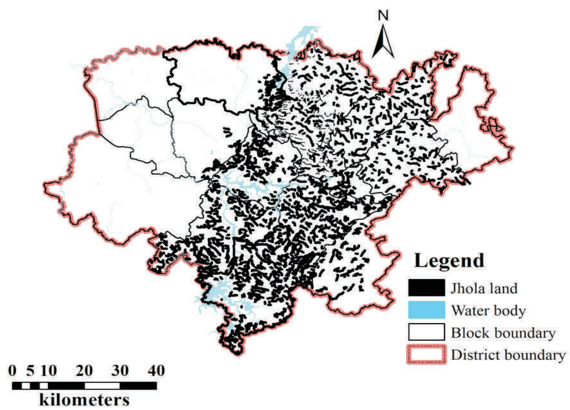



**Fig. 3.8 :** *Jhola* land map of different blocks of Koraput district

**Table 3.6.** Catchment characteristics of *Jhola* land systems (sample based)

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

# 4. Geomorphic Features and Geology of *Jhola* Land

## 4.1 Geomorphic Features of *Jhola* Land and their Characterization

Physiographically, the entire *Jhola* land and its catchment area occupied by forest, highly rugged mountain, interspersed with narrow intermontane valleys. Some of the *Jhola* land catchment is devoid of vegetation due to denudation of bare patched of shifting cultivation. Degraded soils with exposed rocks resulted from severe erosion is the common landscape. The elevation of the hilly terrain ranges from 700 to 1655m above msl with the highest peak of 1655 m above msl. North-western and west-west central parts are characterized by gently undulating plain dotted with isolated hillocks. The major geomorphic features in *Jhola* land development are identified and presented in Table 4.1.

## 4.2 Relationship of Water Holding Capacity with Geomorphic Features and Geology of Catchment Area

Features like geological set up, rainfall distribution and the degree of primary and secondary porosity controls the hydro-geological framework of a place. The dominant geomorphic units identified in the catchment area are denudational hill, residual hill and flood plain. The study area is underlain by diverse rock types of different geological formations which results in contrasting water bearing properties. The major part of the study area is underlain by hard, crystalline rocks. Depending on the nature of formations and their water bearing capacities etc, the rock formations of the area is divided broadly into three major hydro-geological units such as - consolidated, semi-consolidated, and unconsolidated formations.

### 4.2.1 Consolidated Formation

It includes all types of hard rocks of Eastern Ghats Group such as granite, gneiss, khondalite, charnokite, quartzite, limestone and shale of Chhatisgarh Group. These rocks are devoid of primary porosity. The secondary porosity in these rocks developed as a result of weathering and fracturing due to major and minor tectonic movements along with climatological actions. The secondary porosity forms the conditions for movement of groundwater and also acts as reservoir of groundwater. Groundwater occurs under water table conditions in weathered residuum while it occurs under semi confined to confined conditions in the fractured and jointed rocks. The hydro-geological characteristics of different rock formations falling under consolidate unit are described below

- ***Granite Gneisses*** -Most prominent rock types among all other rocks falling under consolidated unit. The thickness of weathered residuum ranges

**Table 4.1:** Geomorphic features in *Jhola* land development

| Types | Characteristics |
|---|---|
| Denudational hills | Group of massive hill ranges intersected with narrow inter-montane valleys favourable for forming shallow aquifers while deeper aquifers are controlled by faults and fractures. |
| Residual hills | Massive hills of moderate areal extent surrounded by plain. Not favourable for groundwater |
| Structural hills | Linear to curvilinear hills at large areal extent showing definite structural control, however moderate amount of infiltration takes place through fractures |
| Intermontane valley | Flat valleys surrounded by hills all around, highly favourable locales for groundwater occurrence due to good recharge from surrounding hills |
| Structural valley | Narrow valley within the structural hill formed along the structurally weak planes. Highly favourable for groundwater occurrence and is sometimes marked with spring |
| Deeply weathered pediplain | The pediplain generally present gently undulating topography with the thickness of weathered zone ranging between 5 to 20 m with the average thickness around 12 to 15 m. These are favourable locales for groundwater occurrences. Deeper aquifers are controlled by lithology and structures |
| Mesa/Butte | Flat topped hill with escarpment on both the sides. Perched water bodies of limited extent may occur depending on the width of the plateau |

from negligible to 34 m. The yield of the wells depends on the thickness of the water-saturated zone as also the number of intersecting fracture tapped. The yield of the wells located in granitic terrain is considerably more than those in khondalitic terrain.

- ***Khondalites***-Khondalite suite of rocks are highly metamorphosed, intensely folded with deep fractures. Ground-water occurs under unconfined to semi-confined conditions.

- ***Charnokite***-Due to hard, compact and massive nature of this formation, the thickness of weathered residuum is limited. The weathering is not very pronounced in depth. The spacing of joints is wide apart. The depth to water level in phreatic aquifer is of limited areal extent.

- ***Quartzite/gneiss***-The thickness of weathered residium varies from 10 to 12 m. The phreatic aquifer in this formation is of limited areal extent.

- ***Limestone***-This formation is generally of limited areal extent. Groundwater occurs in weathered residuum in unconfined to confined conditions.

### 4.2.2 Semi-Consolidated Formation

- ***Laterite*** - Highly porous in nature and are formed as capping over the older formations as residual product. The lateritic profile extends down to a depth of 10-20 m. Hydrologically lateritic aquifer has the potentiality of yielding groundwater.

### 4.2.3 Unconsolidated Formations

- ***Alluvium*** - Alluvium of recent to sub-recent age constitutes the unconsolidated formation bring above comprising of gravel, sand and clay and occur as discontinuous patches along the drainage channels. The maximum thickness of the alluvium is in the order of 20-23 m. Due to high degree of porosity and permeability the alluvial strips constitute the moderately potential aquifers. Groundwater occurs under semi-confined to confined conditions.

## 4.3 Geology and Soils of *Jhola* Land

The Eastern Ghats belt is regarded as an orogenic belt formed during the Indo-Antarctica collisional events in the Proterozoic (Grew and Manton, 1986; Mezger and Cosca, 1999; Dobmeier and Raith, 2003; Dasgupta and Sengupta, 2003). The belt extends linearly in north east-south west direction, and contains several lithologic domains parallel to its trend (Narayanaswamy, 1975; Nanda and Pati, 1989; Ramakrishnan et al., 1998). The belt is dominated by granulite facies rocks, and consist primarily of migmatitic quartzo-feldspathic para - and orthogneisses that host charnockites, enderbites, massif anorthosites and alkaline complexes. On the basis of available geologic and geomorphic information, the Eastern Ghats belt can be subdivided into several provinces (Rickers et al., 2001; Dobmeier and Raith, 2003).The Eastern Ghats province that host the Koraput complex, is correlated with Rayner complex of East Antarctica on account of the near synchronous pervasive deformation, high-grade metamorphism and crustal derived magmatism (between 1.1 and 0.9 Ga) in the two areas (Mezger and Cosca, 1999; Kelley et al., 2002).

The major part of Koraput district is underlain by the rocks of the Eastern Ghats group of Pre-Cambrian age which has undergone multiple deformations as revealed by the presence of structural features like fold, faults, joints, foliation etc. The consolidated rocks of upper to middle Proterozoic age occupy a small portion of north-western part of the district. The recent to sub-recent alluvium occurs as thin and discontinuous patches in limited scale along the prominent drainage channel. Almost all the *Jhola* land are developed over these alluviums. Laterite occurs as their capping over the country rocks in isolated pockets. There are at least five major tectonic events represented by north east-south west, east north east-west south west, north-south, north west-south east and north north east-south south west tectonic patterns in chronological order. Granite gneisses exhibit gneissosity in north north east-south south west direction. Khondalite are highly fractured and sheared, where as charnockite are usually massive and compact in nature. The rocks of Chhattisgarh group are gently folded with low dips of both the limbs ($4^0$-$11^0$). The fold axis trends in N $35^0$ E - S $35^0$ E.

## 4.4 General Geological Formation

- ***Khondalites*** - A regional metamorphosed suite of rocks comprises mainly of quartz - garnet sillimanite gneiss and schist, garnetiferous sillimanite gneiss and schist, garnetiferous sillimanite quartzite and calc-granulite, which occurs in an interbedded sequence. Khondalite are found associated with charnockite and porphyroblastic granitoid gneiss. The rocks are grayish brown to reddish brown in colour and are well foliated. The occurrence of quartzite and calc granulites are very limited and sporadic.

- ***Quartzite -*** These are metasediments and comprises of quartzite, garnet andalusite gneiss of Bengal Group and occupying limited area in western part of the district.

- ***Charnockite-*** It is product of deep seated metamorphism of quartzo-feldspathic rocks- many of which were initially igneous. This suite of rocks comprises of pyroxene granulite (basic), hypersthene granite and granodiorite (acid and intermediate) and is distributed in south and central part of the area. The acid and intermediate variety of charnockite is more prominent and form longer bodies than the basic variety. Texturally they are fine to coarse grained, greenish grey colour having greasy lustre and consist of quartz, k-feldspar, Na plagioclase, oligoclase, hypersthene, garnet, magnetite and biotite minerals.

- ***Granite Gneiss*** - Rock types of Eastern Ghats Group formed during high grade regional metamorphism occurs in the undulating plains and sometimes forms hills and hillocks. These rocks are mostly represented by biotite gneiss, porphyritic granitic gneiss etc. They are porphyritic and non porphyritic in nature and are usually grey to light grey in colour and consist of regular alteration of schistose (mica, amphibole and pyroxene minerals) and granulose (quartzo feldspathic minerals) bands.

- ***Shale, limestone and quartzite*** - These rocks occur uncomformably over granite gneisses, slightly metamorphosed and consist of white non feldspathic quartzites, impure limestone and purple shales and belong to Chattisgarh Group of middle to upper Proterozoic age and are exposed in the north-western part of the area and best exposed around Gupteswar - Ramgiri area in Boipariguda blocks.

- ***Laterite***–Laterites are reddish, porous, concretionary material occurs as capping over the country rocks with considerable thickness and formed due to intensive weathering under extreme oxidizing conditions in tropical to sub-tropical climate.

- ***Alluvium-***Alluvium of recent origin comprising of sand, silt and clay of limited extension and thickness occurs in pockets along major drainage channels. They are generally fine to coarse grain in nature

The distribution patteren of different lithological units in koraput distrcrit in shown on fig. 4.1

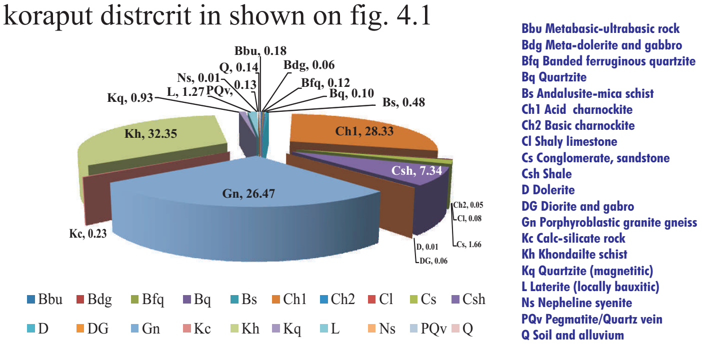



**Fig. 4.1:** Distribution of different lithology units in Koraput district

## 4.5 Geological Formations of *Jhola* Land and their Structural Controls

The surface geology of some of the selected *Jhola* land with its catchment were studied in details, which are explained below:

**a. Pakjhola**

The dominating geology of upper catchment of Pakjhola is khondalite group of rocks with the elevation of 1055m msl. The central part of *Jhola* (both on upper and lower side) is dominated by basic granulite while the lower catchment of both the *Jhola* side is dominated by rocks of acid charnockite up to Semiliguda. The elevation difference from lower to upper *Jhola* varies from 902 to 1057 m above msl with the occurrence of laterite as pockets in the central upper part of *Jhola* land as well as in the upper catchment. Catchment of both the sides is highland with elevation range of 1057-1031 m from upper to lower side. Structural control of *Jhola* land is trending north east-south west with dip amount of 50-80°. The succeeding geology of Pakjhola is khondalite>basic charnockite>acid charnockite> laterite> alluvial soil.

**b. Sisaguda**

*Jhola* land belongs to Pottangi block, Koraput district. Geology of the catchment area as well basement of *Jhola* land system is dominated by the acid charnockite group of rocks with elevation range of 925-1077 m above msl. Structural control of *Jhola* land is trending north east-south west with dip amount of 35º.The succeeding geology of Sisaguda *Jhola* is acid charnockite> alluvial soil.

**c. Podapadar**

Geologically and structurally, it is similar to Sisaguda as the catchment area as well basement of *Jhola* system is dominated by the acid charnockite group of rocks with elevation range of 979-1183m above msl. Elevation difference of upper-middle-lower *Jhola* is 994-975-954 m msl. Structural control of *Jhola* land is trending north east-south west with dip amount of 35°. Soil texture varies from silty clay loam to sandy clay loam.

**d. Mohanpada**

*Jhola* is developed in khondalite suite of rocks. The lower and upper lower side of the catchment area is dominated by the acid charnockite group of rocks with elevation difference of 888-950m above msl. Structural control of *Jhola* land is trending north east-south west with dip amount of 60-70º. The succeeding geology of this *Jhola* is khondalite>acid charnockite>alluvial soil.

**e. Malitala**

*Jhola* is developed over khondalite suite of rocks both in the basement as well as in the catchment. Acid charnockite group of rocks are developed in pockets in the upper catchment side of middle *Jhola* land. Laterite patches are also developed in the upper catchment of *Jhola*. Elevation ranges of catchment vary from 1145-972 m above msl. Rocks of the area are foliated and jointed and beddings are inclined from 60-75° along the *Jhola* land with strike direction of north east-north west which controls their structural development. Surface and sub-surface soil texture varies from silty clay loam to sandy clay loam in the upper and middle of *Jhola* land.The succeeding geology of Malitala is khondalite>acid charnockite>laterite>alluvial soil.

**f. Ambiti Ambaguda**

*Jhola* land is developed in khondalite suite of rocks with upper catchment dominated by laterites. The elevational difference varies from 1143-1136-1048 m above msl and beddings are inclined to the degree of 70-75°and their strikes are north east-south west direction. Surface and sub-surface soil texture of upper and lower *Jhola* is silty clay loam while it is sandy clay loam in the middle *Jhola* land.The succeeding geology of the ambiti ambaguda *Jhol*a is khondalite> laterite>alluvial soil.

**g. Lohaba**

*Jhola* land is developed in khondalite suite of rocks with granite gneiss of migmatite group of rocks in the central part of *Jhola*. Catchment rock in the lower and upper lower side of *Jhola* is dominated by acid charnockite with altitudinal differences of 917-907m msl. The bedding is inclined to 70º and their strikes are north east-south west direction which is parallel to the *Jhola* land. The succeeding geology of the Lohaba *Jhola* is khondalite>granite gneiss> alluvial soil.

**h. Sukuguda**

Basement as well catchment areacountry rocks of *Jhola* land is acid charnockite with altitudinal differences of 905-1022 m above msl. The bedding is inclined to the degree of 50° and their strikes are north east-south west direction which is parallel to the *Jhola* land. The succeeding geology of the *Jhola* is acid charnockite>alluvial soil.

**i. Chhapra**

Geologically and structurally it is similar to Sukuguda *Jhola* land with basement as well catchment area country rocks is acid charnockite with altitudinal differences of 905-1022 m above msl. The bedding is inclined to the degree of 50º and their strikes are north east-south west direction which is parallel to the *Jhola* land. The succeeding geology of the *Jhola* is acid charnockite> alluvial soil.

**j. Dumuripadar**

Geologically *Jhola* land is developed in khondalite suite of rocks in association with acid charnockite in the basement as well as in the catchment area with altitudinal differences of 1200-900 m above msl. The bedding is inclined to the degree of 70-75º and their strikes are north east-south west direction. The succeeding geology of the *Jhola* is khondalite>acid charnockite> alluvial soil.

**k. Ankadali**

Geologically *Jhola* land is developed in acid charnockite rocks in the basement as well as in the catchment area with altitudinal differences of 893-842m above msl from upper to lower side of *Jhola*. Laterites are developed as pockets in the upper and lower catchment of upper *Jhola*. The bedding is inclined to the degree of 70º and their strikes are north-south direction. The succeeding geology of the *Jhola* land is acid charnockite>laterites.

**l. Badigada**

Geologically this *Jhola* land is developed in acid charnockite rocks in the basement as well as in the catchment area with altitudinal differences of 878-845m above msl from upper to lower side of *Jhola*. The bedding is inclined to the degree of 70º and their strikes are north-south direction. The succeeding geology of the *Jhola* is acid charnockite> laterites.

**m. Jhola Jhanjar**

Geologically this *Jhola* land is developed in acid charnockite rocks in the basement as well as in the catchment area with altitudinal differences of 884-847 m above msl from upper to lower side of *Jhola* land. The bedding is inclined to the degree of 55-70º and their strikes are north east-south west direction. Laterites are developed as pockets in the lower and upper catchment of lower *Jhola* land. Quartz-garnet-sillimanite-schist/gneiss group of rocks are also developed in the upper and lower catchment of lower *Jhola* land. The succeeding geology of the *Jhola* land is quartz-garnet-sillimanite -schist/gneiss>acid charnockite> laterites.

**n. Tusuba**

Geologically this *Jhola* land is developed in acid charnockite rocks in the basement as well as in the catchment area with altitudinal differences of 885-863 m above msl from upper to lower side of *Jhola* land. Laterites are developed as pockets in the upper catchment of upper part of *Jhola* land. The bedding is inclined to the degree of 70° and their strike direction is north east-south west. Joints are vertical with 55° inclinations and their direction is same as strike of the bedding plane.

**o. Doliguda**

Geologically this *Jhola* land is developed in acid charnockite rocks in the basement as well as in the catchment area with altitudinal differences of 872-858 m above msl from upper to lower side of *Jhola* land. Granite gneiss is developed in the upper catchment of lower *Jhola* land. Laterites are developed as pockets in the lower part of middle *Jhola* and upper catchment of lower *Jhola*. The bedding is inclined to the degree of 70° and their strikes are north east-south west direction. The succeeding geology of the *Jhola* land is granite gneiss>acid charnockite> laterites.

# 5. Resource Characterization of *Jhola* Land

## 5.1 Soil Fertility Status

Soil is a vital natural resource, which supports life, and its optimum use at any place influences the socio-economical development of people of that area. It provides food, fodder and fuel for meeting the basic human and animal needs. With the increase in population, the pressure on the soil to meet the food security is increasing, and consequently resulting with nutrient depletion from the soil. Further, the capacity of a soil for agricultural production is limited and the limits to production are set by intrinsic characteristics of soils, agro-ecological settings, land use and management. This demands systematic appraisal of the soil resources with respect to their extent, distribution, characteristics, behaviour and use potential, which is very important for developing an effective land use system for augmenting agricultural production on a sustainable basis. The soils of the *Jhola* land are at saturation condition for most time of the year. These are soils with impeded drainage either because of flooding or because of a high groundwater table including ponding, to the extent that it influences their development and properties, and land use potentials.

*Jhola* land soils from different blocks of the study area were collected from 0-20 cm, and 20-40 cm depth from the upper, middle and lower positions of the *Jhola* systems. The collected samples were analyzed for major physical and chemical soil quality parameter like pH, Electrical Conductivity (EC), Organic Carbon (OC), Nitrogen (N), Phosphorous (P), and Potassium (K). Apart from major nutrients, micro-nutrients like Cu, Zn, Fe, and Mn were also analyzed. Table 5.1 and 5.2 summarizes the results of the soil physico-chemical parameters analyzed for the soil depths 0-20 cm and 20-40 cm**.**

**Table 5.1 :** Physico-chemical properties of *Jhola* land soil for the depth of 0-20 cm

| Blocks | pH | EC (dS/m) | OC (%) | N (kg/ha) | P (kg/ha) | K (kg/ha) |
|---|---|---|---|---|---|---|
| Koraput | 4.6 | 0.726 | 0.9 | 275.5 | 13.6 | 323.2 |
| Semiliguda | 4.8 | 0.890 | 0.8 | 228.6 | 15.5 | 230.0 |
| Laxmipur | 4.4 | 0.788 | 1.0 | 293.9 | 15.0 | 305.3 |
| Potangi | 5.1 | 0.828 | 0.7 | 179.2 | 18.8 | 224.3 |
| Lamtaput | 4.5 | 0.795 | 1.1 | 237.0 | 22.1 | 164.3 |
| Dasmantpur | 4.8 | 0.812 | 1.0 | 219.6 | 13.1 | 165.3 |
| Narayanpatna | 4.9 | 1.160 | 1.0 | 226.9 | 16.2 | 90.6 |

**Table 5.2:** Physico-chemical properties of *Jhola* land soil for the depth of 20-40 cm

| Blocks | pH | EC (dS/m) | OC (%) | N (kg/ha) | P (kg/ha) | K (kg/ha) |
|---|---|---|---|---|---|---|
| Koraput | 4.3 | 0.577 | 0.9 | 291.7 | 10.6 | 346.7 |
| Semiliguda | 4.7 | 0.502 | 0.7 | 277.8 | 17.2 | 190.3 |
| Laxmipur | 4.5 | 0.560 | 1.0 | 247.0 | 13.5 | 225.5 |
| Potangi | 5.2 | 1.359 | 0.7 | 176.4 | 20.3 | 182.8 |
| Lamtaput | 4.7 | 0.445 | 0.8 | 173.7 | 23.7 | 139.5 |
| Dasmantpur | 5.0 | 0.457 | 1.0 | 213.6 | 13.7 | 158.9 |
| Narayanpatna | 5.0 | 0.897 | 1.0 | 226.4 | 13.7 | 102.1 |

### 5.1.1 Chemical Properties and Fertility Status of the *Jhola* Land Soils

**Soil pH and EC :** The pH values in the studied *Jhola* land area ranged from 4.4 to 5.1 in the surface soils and 4.3 to 5.2 in the sub-surface soils with mean and standard deviation (SD) values of 4.7 and 0.24; and 4.8 and 0.30, respectively with very low variability (CV) between the *Jhola* land (Table 5.1 and 5.2). The soils were strongly acidic to very strongly acidic in nature. The EC values ranged from 0.726 to 1.160 dS/m in the surface soils and from 0.445 to 1.359 dS/m, in the sub-surface soils with mean and SD values of 0.9 and 0.7 dS/m, and 0.14 and 0.33 dS/m, respectively.

**Organic carbon :** The organic carbon content ranged from 0.7 to 1.1% in the surface soils and 0.7 to 1.0% in the sub-surface soils with mean and SD values of 0.9 and 0.11%; and 0.9 and 0.12%, respectively with very low variation (CV) between the soils of different *Jhola* land sites (Table 5.1 and 5.2). Therefore the soils of the study area can be categorized as medium to high in terms of OC. The organic carbon content of surface soil was slightly higher than sub-surface soil in all the studied *Jhola* land sites with only minor exception.

**Available nutrients :** Available N status varied from 179.2 to 293.9 kg/ha for surface soils and 173.7 to 291.7 kg/ha for sub-surface soil, with an average value of 237.2 and 229.5 kg/ha at 0-20 cm and 20-40 cm depth, respectively (Table 5.1 and 5.2). At both the sampling depths, soils were low to medium in available N in terms of soil fertility rating (Nelson and Somners, 1996). About 67.3% of sampling sites with low and 32.7% were medium in available N at both the depths. The available P content in the *Jhola* land soils varied between 10.6 and 23.7 kg/ha at both the soil sampling depths which is considered to be medium to high in terms of soil fertility rating (Nelson and Somners, 1996). Only 13.5 % of the *Jhola* land soils were high in available P content whereas the rest 86.5 % of the soils were medium in available P content. The mean and SD of available P content was 16.3 and 3.15 kg/ha and 16.1 and 4.56 kg/ha, respectively. The status of available K content in the *Jhola* land soils ranged from 90.6 to 346.7 kg/ha at both the sampling depths which is rated as low to high in terms of soil fertility (Nelson and Somners, 1996). No clear trend was observed between the sampling depths with respect to available K, but variation between the *Jhola* land was high as indicated in CV (38.4 and 40.9 % at 1$^{st}$ and 2$^{nd}$ soil depths). The mean and SD of available potassium content was 214.7 and 82.35 kg/ha and 192.2 and 78.61 kg/ha, respectively.

## 5.2 Comparison of *Jhola* Land Soils with Upland Soils

The tillage / tilth are not as important in paddy soils as in upland soils. As long as enough water is available to keep the soils submerged, the balance between water retention and aeration, which is vital for upland soil, can be disregarded. Furthermore, a heavy clay soils with a very hard, dry consistency is difficult to till in upland conditions, but is relatively easy to plough and till in flooded low lands with animals and even manually by using spade. The high level of resistance of paddy soils to erosive forces is even more important, from the viewpoint of sustainability. Upland soils tend to be eroded away unless they are properly protected. This is particularly true in the tropics, where the erosivity of rainfall is very high and where upland soils usually have poor resistance to erosion. *Jhola* land soils (cultivated with paddy) are most resistant to erosion when they are terraced and there are ridges around the field, as measures to retain surface water. In addition, paddy fields in the lowland receive new sediments deposited from run-off that carries eroded topsoil down from the upland, thus perpetuating soil fertility and productivity.

In upland farming, crop rotation is a necessity to avoid a decline in yield due to diseases and pests that arise from a monoculture situation (soil sickness). On the other hand, paddy can be grown year after year without any clear sign of yield decline, over a considerable length of time in the same field. The alternation from aerobic to anaerobic conditions in a yearly cycle of paddy farming is the best measure to remove the causes of soil sickness. No pathogens or soil-borne animals can survive such a drastic change in the redox environment.

## 5.3 Crops, Cropping Pattern and Productivity

Almost throughout the year, *Jhola* land soils are usually saturated and anaerobic. However during summer season the soils of the upper *Jhola* land, and to some extent the middle *Jhola* land dries up, and in that time aerobic conditions prevail. Under aerobic conditions the ammonium ($NH_4$) form of soil mineral N is oxidized to nitrate ($NO_3$) which may accumulate in the soil or be utilized by the crop grown there. Most of the $NO_3$ that is not utilized by the plant may be lost through leaching and denitrification when the soils are subsequently flooded during the rainy season.

Under traditional farming in Koraput district, only one crop, that is paddy grown in the *Jhola* land throughout the year depending on the moisture availability in the field. Some farmers grow one single crop of low land paddy (lowland paddy-fallow) in the main season (June-November) and abandon the *Jhola* land until the following year. Most farmers practice double cropping (low land paddy-low land paddy) in the *Jhola* land. The lowland paddy is planted in the main cropping season between June and July when the rains have become steady and is harvested in November and December depending on the length of maturity of the variety.

## 5.4 Land Capability and Suitability Classification

The *Jhola* land are mainly formed along the stream beds with the farmers modified it to suit the paddy cultivation. The lower *Jhola* land can be classified according to the USDA Land Capability Classification (LCC) as Class IVw. The middle *Jhola* land can be classified as Class IIIc and the upper *Jhola* land can be classified as Class IIIs.

The mapping units for lower, middle and upper parts of *Jhola* land are given below

For lower part of *Jhola* land:

$$\frac{SiCL-d_5}{C-e_2}$$

For middle *Jhola* land:

$$\frac{L-d_5}{C-e_2}$$

For upper *Jhola* land:

$$\frac{LS-d_1}{D-e_2}$$

## 5.5. Hydrochemistry of *Jhola* Water and Indices for Irrigation

*Jhola* water quality was generally good as evidenced from the hydro-chemical parameters (Table 5.3). The pH value did not vary too much between different *Jholas* in the study area. The pH of *Jhola* water varied from 3.6-6.7 indicating strongly to acidic in nature, which was also supported by the presence of large amounts of $HCO_3$ (4.9-87.8 ppm) and $SO_4$ (4.5-11.0 ppm). Conductivity is a good and rapid method to measure the total dissolved ions and is directly related to total solids. *Jhola* water of the entire study area was non-saline as evidenced from EC values, which ranged from 0.02-0.35 ds/m.The bicarbonate concentration of *Jhola* water ranged between 4.9 and 87.8 ppm and mainly precipitated as calcium and magnesium bicarbonate. No carbonate content was detected from the selected *Jholas* under study. Chloride concentration varied from low to medium (14.2-62.5 ppm) and mainly concentrated in the areas surrounded by forests. The hardness is the parameter of water quality used to describe the effect of dissolved minerals (mostly Ca and Mg). The Ca concentration in the water was in the range of 2.4-13.6 ppm with the mean value of 5.86 ppm where the Mg concentration varied between 1.92 and 12.96 ppm. The sodium concentration in the *Jhola* water varied from 0.8-14.2 ppm with an average value of 2.64 ppm. On the other hand, potassium concentration was very low (0.6-7.9 ppm).

**Table 5.3 :** Hydro-chemical properties of water collected from different *Jhol*a land of Koraput district

| Parameters | Min | Max | Mean | SD | CV (%) |
|---|---|---|---|---|---|
| EC (dS/m ) | 0.02 | 0.35 | 0.09 | 0.06 | 68 |
| pH | 3.60 | 6.70 | 6.05 | 0.72 | 12 |
| Ca (ppm) | 2.40 | 13.60 | 5.86 | 2.23 | 38 |
| Mg (ppm ) | 1.92 | 12.96 | 7.42 | 2.91 | 39 |
| Na (ppm) | 0.80 | 14.20 | 2.64 | 1.07 | 41 |
| K (ppm) | 0.60 | 7.00 | 2.01 | 1.42 | 71 |
| $HCO_3$ (ppm ) | 4.90 | 87.80 | 36.08 | 21.92 | 61 |
| Cl (ppm) | 14.20 | 62.50 | 24.36 | 7.06 | 29 |
| $SO_4$ (ppm) | 4.50 | 11.00 | 6.62 | 1.51 | 23 |
| $NO_3$ (ppm ) | 7.40 | 35.00 | 16.64 | 5.86 | 35 |
| TDS | 11.50 | 166.40 | 52.02 | 22.90 | 44 |
| Hardness | 3.10 | 13.30 | 8.13 | 2.86 | 35 |
| Alkalinity (ppm) | 4.00 | 72.00 | 29.00 | 18.30 | 63 |

The water quality indices (Table 5.4) indicated the suitability of *Jhola* water for irrigation as there was no sodicity hazard. The Sodium Adosrption Ratio (SAR) and Exchangable Sodium Percentage (ESP) were all very low and possessed no threat of sodicity. SAR and ESP ranged between 0.11-0.91 and 0.05-0.55, respectively, with average values of 0.24 and 0.12 respectively.

**Table 5.4:** Water quality indices for judging the suitability of *Jhola* water for irrigation

| Indices | Min | Max | Mean | SD | CV (%) |
|---|---|---|---|---|---|
| SAR | 0.11 | 0.91 | 0.24 | 0.09 | 36.1 |
| RSC | 1.00 | 1.00 | -0.32 | 0.44 | 137.8 |
| ESP | 0.05 | 0.55 | 0.12 | 0.04 | 31.3 |
| PI | 50.96 | 258.62 | 91.12 | 44.30 | 48.6 |
| LSI | 0.82 | 1.30 | 1.05 | 0.17 | 16.2 |

Permeability Index (PI) were calculated to judge the quality of irrigation water in relation to soil for agricultural development. According to this index water can be classified into three classes. Class I and class II water with 75% or more of maximum permeability is suitable for irrigation purpose, while class III water having 25% of maximum permeability is not suitable. In the present study the PI ranged from 50.96-258.62 meq/l (Table 5.4). Problems of scaling in industrial large boilers as well as domestic utensils can be judged by Langelier Saturation Index (LSI) but it provides no indication of how much scale or calcium carbonate will actually precipitate to bring water to equilibrium. It simply indicates the driving force for scale formation and growth in terms of pH as a master variable. Calculated LSI values, given in Table 5.4 showed that 100% of the samples have positive LSI values.

# 6. Management Practices and Productivity of *Jhola* Land

'*Jhola*' is a perennial stream in hilly area of southern Odisha and land on either side are leveled or terraced for cultivation of paddy by diverting water from the stream. The diverted stream water is conveyed to the paddy fields and surplus water move from one field to other and again joining to the main stream at lower reach.

## 6.1 Owndership of Land

*Jhola* land ownership is purely individual and just adjacent to the main stream where stream beds are leveled or terraced for cultivation. The *Jhola* land may not have ownership right, mostly the land owners having land on stream bank try to encroach the streambeds for cultivation purpose.

## 6.2 Soil and Water Conservation Measures

Paddy is the predominant crop cultivated in the *Jhola* land since the soil is deep and fertile due to deposition of eroded soil from the upper catchment. The land is converted into perfectly leveled small terraces with compartmental bunding to facilitate water to impound for paddy cultivation.

The cross section of the bunds varies from 0.09 sq. m to a maximum of 0.40 sq. m. The side slope of the bunds is very steep due to seasonal cleaning and shape of bunds. Each field bunds are provided with surplus arrangement to drain out excess water. In general, bunds are stabilized with planting of *sambuta* grass (*Saccharum* spp.) which is available locally. This *sambuta* grass provides good stability to bunds and having deep and profuse rooting pattern (Fig. 6.1). The *sambuta* grass is widely adoptable to both water logging and dry conditions and it's a non grazing grass. At water courses and wherever bunds are weak, knitted vegetative brushwood mat like structure is being used for stabilization.

**Fig. 6.1:** Vegetative barrier *Sambuta* grass in paddy field

## 6.3 Land and Crop Management

### 6.3.1 Land Preparation

Land preparation is done both manually with the help of spade and bullock or buffalos depending upon the availability of resources. Majority of the farmers do manual land preparation compared to use of animals. Desi wooden or iron plough is used for ploughing the field by animals.In general two ploughing done in both the directions (along and across) and leave the field for a week. Then immediately field is leveled with the help of wooden leveler for facilitating uniform standing of water to a depth of 10 cm for 10 to15 days to facilitate decomposition of organic residues while ploughing or soil working. Final ploughing and leveling is done after decomposition of organic residues and immediately on the same day or in next day transplanting begins.

### 6.3.2 Land Leveling

Leveling of field is done before and during land preparation. Before ploughing, leveling is done when eroded soil from other field is deposited in the field and normally done before the main land preparation begins with the help of spade (Fig. 6.2). Normally farmers do this operation while strengthening the field bunds. Land leveling is done in two phase during field preparation.

**Fig. 6.2 :** Land preparation in paddy field

**Phase I: -** Immediately after second ploughing

**Phase-**II:-At the time of final land preparation immediately after the ploughing operation is over. From the secondary data total labour inputs required for rice production in *Jhola* systems was estimated. A total of 210 h/ha animal and labour inputs was required for land preparation and land leveling operation which accounted 10.6% of the total labour inputs under rice production in *Jhola* systems. Men and women labour shared 78 and 22%, respectively in land preparation and land levelling. The total animal and labour energy required was about 2019.4 MJ (Animal: 1624 MJ, Men: 322.4 MJ and Women 73.4 MJ) which was 38% of the total labour inputs (Fig. 6.3, 6.4, 6.5 and table 6.1).

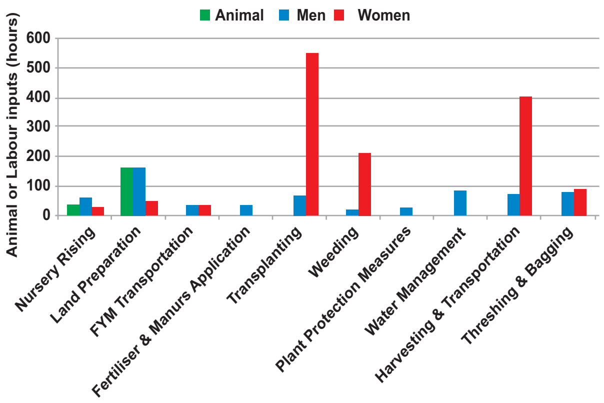



**Fig. 6.3**: Component wise animal and labour inputs under *Jhola* land rice production system

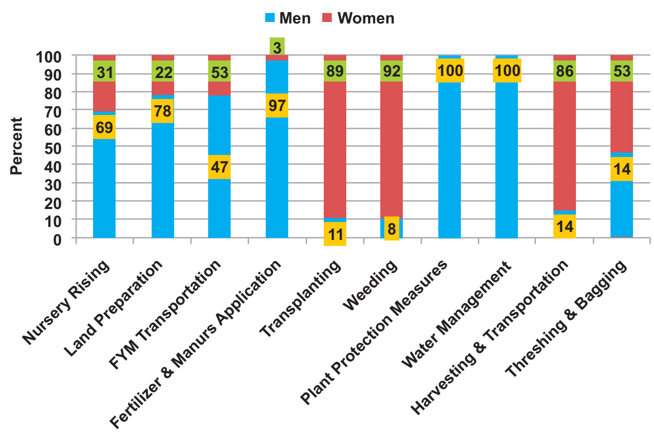



**Fig. 6.4:** Component wise percent labour inputs under *Jhola* land rice production system

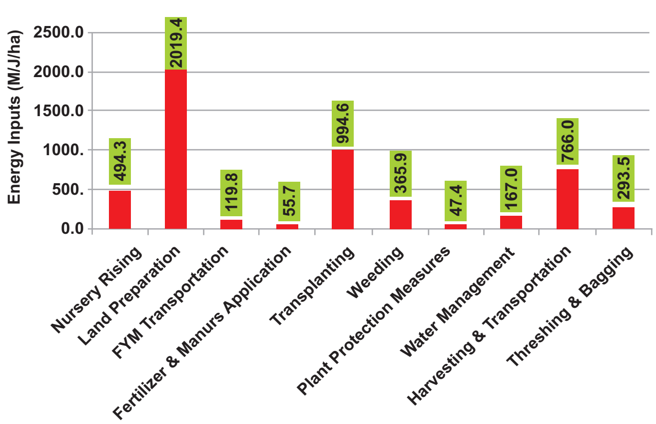



**Fig. 6.5:** Crop management practice wise labour energy inputs in rice under *Jhola* land

**Table 6.1 :** Details of energy inputs and out puts in *Jhola* land rice production system

| Input and output | Quantity/ha | Total energy (MJ/ha) | Percent |
|---|---|---|---|
| A. Inputs | | | |
| 1. Animal and labour (h) | | | |
| a. Men | 625 | 1225.4 | 14.39 |
| b. Women | 1363 | 2140.1 | 25.14 |
| c. Animals | 194 | 1958.7 | 23.01 |
| Total internal energy input | | 5324.2 | 62.54 |
| 2. Externalinputs (kg/ha) | | | |
| a. Nitrogen | 34.52 | 2091.9 | 24.57 |
| b. Phosphorus | 16.00 | 177.6 | 2.09 |
| c. Potash | 11.00 | 73.7 | 0.87 |
| d. Farmyard manures | 271.00 | 81.3 | 0.95 |
| e. Chemicals | 0.34 | 3.4 | 0.04 |
| f. Seed | 52.8 | 761.4 | 8.94 |
| Total external energy input | | 3189.3 | 37.46 |
| Total energy input | | 8513.5 | 100.00 |
| B. Output (kg/ha) | | | |
| a. Rice grain yield | 2580.4 | 37209.4 | 54.02 |
| b. Rice straw yield | 3154 | 31665.0 | 45.98 |
| Total output energy | | 68874.4 | 100.00 |
| Net energy (MJ/ha) | | 60361 | |
| Energy use efficiency (%) | | 11 | |
| Energy productivity (kg/MJ) | | 0.3 | |
| Specific nergy (MJ/kg) | | 3.3 | |
| Internal to external energy input ratio | | 1.67 | |

### 6.3.3 Raising of Paddy Nursery

Choice of nursery rising depends on the extent and distribution of land. If farmers having single piece of *Jhola* land, normally nursery bed is raised in the same land. If land is situated in different locations, paddy seedling is raised in one or two location where it is easy for transportation of seedling while transplanting.

Small nursery bed is prepared by turning the soil with the help of spade. Normally three times turning of soil is done. The time gap between turnings of soil is 4 to 5 days. When the nursery bed is larger normally three ploughing (along and across each time) is done keeping 4 to 5 days interval in between. FYM and complex fertilizer are applied during final land preparation. Top dressing of area is done 15-18 days after sowing and when the seedlings attain 10 cm height. It was estimated that average seed input energy was 761.4 MJ/ha which was 24% of the external inputs and 8.94% of the total energy inputs in the production system. On an average a total of 86.4 h/ha animal and labour inputs required for rising nursery which accounted for 4.36% of the total labour inputs in the system. The share of men and women labour inputs were 69% and 31%, respectively. The total average labour input energy was 494.3 MJ/ha which was 9.28% of the total labour energy inputs.

### 6.3.4 Application of Manure and Fertilizer

At the time of final land preparation Gromor (28:28:0) is applied @ 100 kg/ha and within 8-10 days after transplanting when seedling stand, established and root development begins, urea top dressing is done. After weeding urea and MoP is applied @ 75 and 25 kg/ha. On an average 34.5 kg N, 16 kg P and 11 kg K is applied per ha in the rice production system. Besides about 271kg/ha FYM is applied before land preparation. A total of 2424.5 MJ/ha energy input was used interms of chemical fertilizer and FYM which was about 74% of the total external input energy. About 37.5% of the total input energy was from external inputs.

The estimated average labour input for transportation of manures and fertilizer including fertilizer application was found to be 97 h/ha which accounted 4.87% of the total labour inputs of rice production. The average total energy inputs was worked out to be 175.5 MJ/ha which was 3.3% of the total labour energy inputs. The share of men and women labour input were 9.7 and 27% of the total men and women labour inputs respectively (Fig. 6.3, 6.4, 6.5 and Table 6.1).

### 6.3.5 Transplanting

Transplanting is done by women and supported by men (Fig. 6.6). Only few farmers follow proper line spacing and most of the cases they follow random planting. Single seedling is planted on a hill for high yielding varieties and 2-3 seedlings for local varieties. Agriculture department of Odisha is advocating line transplanting for standard rice culture.

**Fig. 6.6 :** Tansplanting in paddy field

Among all the operations, for transplanting the major labour input is required and on an average, it required about 616.8 h/ha which was 31.03% of the total labour inputs. The mean total energy input was found to be 994.6 MJ/ha, which was 18.68% of the total labour energy input. The share of men and women labour input for transplanting of rice was 11% and 89%, respectively indicating major role played by women in transplanting.

### 6.3.6 Weeding

Well prepared land with appropriate water management practice keeps the land away from weed infestation. The weed infestation is aggravated by application of manures and fertilizers. Hence, provision of standing water is very much essential to counter the growth of weeds. If proper water management practice is followed then one weeding is sufficient. Manual weeding is the most common.

In this study, it was found that average labour input required for weeding was 228.6 h/ha which was 11.5% of the total labour input in the production system. Similarly, average energy input was 366 MJ/ha and it was 6.9% of the total labour energy inputs. The share of men and women labour input for weeding of rice were 8 and 92%, respectively, indicating major role played by women in weeding operation (Fig. 6.3, 6.4, 6.5 and Table 6.1).

### 6.3.7 Water Management

Water management is very poor in *Jhola* land farming system. In general flooding is followed in cultivation of paddy crop. The diverted water from the *Jhola* or stream is channelized to field and about 4-10 cm of water always remain in standing condition during the cropping period. Excess water flow from one paddy field to another without any control and ultimately join to the main stream at downstream. Depending upon water availability in the *Jhola* or stream, maximum of two times paddy is being grown in a year. After transplanting 1 to 2 cm depth of water is maintained in the field and with the crop growth, height of standing water is increased even up to 10 cm. At maturity the field is allowed to dry out by cuting-off water from the main stream and to facilitate early harvesting of crop.

In general, *kharif* paddy is taken mostly and during post monsoon season due to decreased flow depth in the stream, only limited area is being cultivated where directed water can reach to those fields. Average labour required for water management was 85.2 h/ha which contributed 4.3% of the total labour input. The energy input was 167 MJ/ha which was 3.1% of the total labour energy input. The share of labour from men is the major and its 100%.

### 6.3.8 Pest and Disease Control

To keep away the pest (Stem borer and Gandhi bug), raw cow dung is diluted with water and the mixture is applied with the help of raw leaf branch. It is believed that the foul smell generated from this mixture will act as a pest repellant. Most of the farmers use standard pest and disease control measures. On an average only 0.34 kg/ha chemicals was used which accounted 3.4 MJ/ha energy input (less than 1% of the external input energy).

Average labour reiquired for application of plant protection chemicals was estimated to be 24.16 h/ha which was 1.22% of the total labour input. The energy inputs were 47.4 MJ/ha which was less than 1.0% of the total labour energy input. The share of labour from men is the major and it is 100%.

### 6.3.9 Harvesting and Threshing

Women are employed for harvesting, bundling, transportation while threshing and cleaning operation are carried out by male .Threshing is done by moving a group of bullock tied together on spread out heap of harvested paddy. During the threshing process, two times turning of the paddy straw is practiced and the process continued till the grains are detached from straw. The average labour required for harvesting, transportation and threshing including bagging was 638.4 h/ha which was 32.1% of the total labour energy input. The average energy input required was about 1060 MJ/ha which was 19.9% of the total labour energy input in the production system. The share of men and women labour input for this operation were 23 and 36%, respectively.

The average animal, men and women labour inputs required for different field operations were found to be 194 (9.75%), 625 (31.44%) and 1363 (68.56%) h/ha respectively. Similarly, average input energy required is 1225.39, 2140.10 and 1958.69 MJ/ha men, women and animal which are 14.4, 24.14 and 23.01% of the total energy inputs required for rice production.

## 6.4 Productivity

Average rice grain and straw yield were 2580 kg/ha and 3154 kg/ha, respectively. The land holding size of the respondents varied between 0.2 ha and 2.0 ha. The grain yield varied from 1482 kg to 4323 kg/ha and straw yield varied from 1811 kg to a maximum of 5283 kg/ha among the respondents.

## 6.5 Energy Inputs and Outputs

Total energy inputs are grouped into internal (direct) and external (indirect) energy inputs. Internal energy inputs

**Table 6.2 :** Direct/indirect, renewable and non-renewable energy inputs in rice production in *Jhola* land

| Indicators | Energy (MJ/ha) | Percent |
|---|---|---|
| Direct energy | 5324.18 | 62.54 |
| Indirect energy | 3189.29 | 37.46 |
| Renewable energy | 6085.56 | 71.49 |
| Non-renewable | 2427.91 | 28.52 |
| Non commercial energy | 3365.49 | 39.53 |
| Total energy input | 8513.00 | 100.00 |

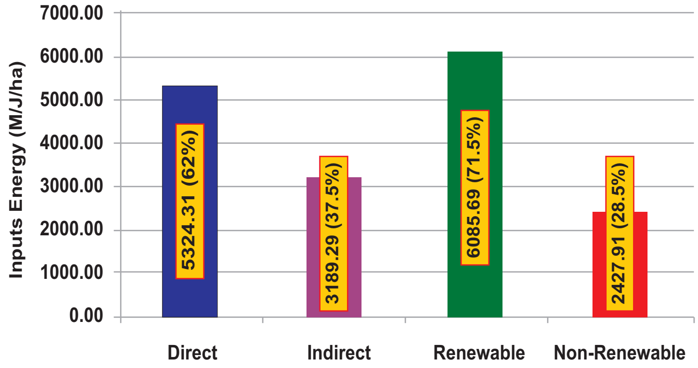



**Fig. 6.7:** Types of energy inputs in rice production under *Jhola* land

are animal and labour inputs, while fertilizers, chemicals and seeds are considered as external energy inputs. Estimated total internal (direct) energy input was about 5324.3 MJ/ha which was 62.5% of the total energy inputs against only 37.5% of the total energy inputs from external (indirect) energy inputs (3189.3 MJ/ha) (Table 6.2 & Fig. 6.7)

Average rice grain and straw yield were 2580 kg and 3154 kg/ha, respectively. The average total energy output accounted about 68874.4 MJ/ha and net energy output was worked out to be 60361 MJ/ha with energy efficiency of 11%. Similarly, energy productivity was found to be 0.3 kg of rice grain per MJ of input energy, the specific energy was 3.3 MJ/kg of rice, and ratio of internal to external energy input was 1.67 indicating more of internal energy input used in the *Jhola* land rice production system. In the *Jhola* land rice production system the renewable energy inputs accounted for 71.5% (6085.56 MJ/ha) of the total energy input and non-renewable energy accounted 28.5% (3365.49 MJ/ha) (Fig. 6.7 and Table 6.2).

## 6.6 Global WarmingPotential (GWP)

Global warming potential (GWP) of paddy under *Jhola* land was estimated from the internal and external inputs used in the production system. The amounts of Green House Gas (GHG) emissions from chemical inputs per hectare were calculated by using carbon dioxide ($CO_2$), nitrous oxide ($N_2O$) and methane ($CH_4$) emissions coefficient of chemical inputs (Yousep et al., 2014). GHG emissions can be calculated and represented per unit of the land used in crop production, per unit weight of the produced yield and per unit of the energy input or output (Soltani et al., 2013). In this study the direct emissions from GHGs of chemical inputs were calculated, where as GWP for indirect emissions not calculated due to difficulty in it's calculation. Each greenhouse gas, i.e. $CO_2$, $CH_4$ and $N_2O$ has a GWP, which is the warming influence relative to that of $CO_2$. The emissions are measured in terms of a reference gas, $CO_2$ (IPCC, 1995). The GWP of $CO_2$ (with a time span of 100 years) is 1, of $CH_4$ is 21, and of $N_2O$ is 310. The total emissions of greenhouse gases were determined as follows (Kramer et al., 1999).

**Table 6.3 :** GWP of internal and external inputs in rice production under *Jhola* systems

| Inputs details | Energy (MJ/ha) | $CO_2$ | $N_2O$ | $CH_4$ kg/ha | GWP-$CO_2$ equivalent |
|---|---|---|---|---|---|
| Internal input (labour+animal) | 5324.2 | 396.2 | 0.00000 | 0.00000 | 396.2 |
| N-Fertilizer | 2091.9 | 124.9 | 0.00121 | 0.14907 | 128.4 |
| P-Fertilizer | 177.6 | 21.6 | 0.00043 | 0.03879 | 22.5 |
| KFertilizer | 73.7 | 1.0 | 0.00001 | 0.00142 | 1.0 |
| Chemicals | 3.4 | 7.7 | 0.00003 | 0.00002 | 7.7 |
| Seeds | 761.4 | 54.9 | 0.00000 | 0.00000 | 54.9 |
| | Total | | | | 610.8 |

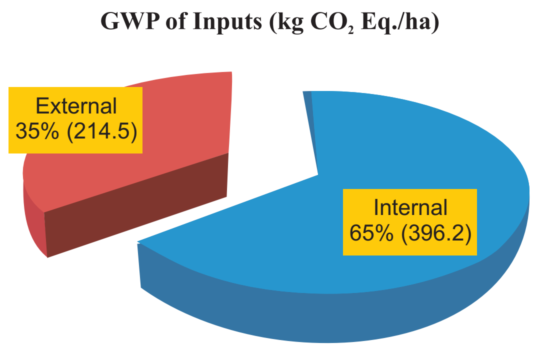



**Fig. 6.8:** Estimated GWP of external and internal inputs in rice under *Jhola* land

Greenhouse effect= ρ $GWP_i \times M_i$, where $M_i$ is the mass (in kg) of the emission gas. The score is expressed in terms of $CO_2$ equivalents. Internal input *viz*., labour energy input was equated with the diesel energy input and accordingly GWP for labour inputs was estimated.

The estimated GWP of rice cultivation under low input *Jhola* land production system was 610.8 kg $CO_2$ Equivalent/ha (Table 6.3). It was observed that 65% of the GWP was from internal inputs and remaining 35% of GWP was contributed from the external inputs like chemical fertilizers, chemicals and seeds (Fig. 6.8). The low GWP is attributed to low external inputs in the rice production system.

## 6.7 Water Use and Water Productivity

Total Consumptive Water Use (CWU) or potential evapo-transpiration of rice grown in *Jhola* land for both *kharif* and summer season was estimated using reference evapo-transpiration ($ET_0$) and crop co-efficient value ($K_c$) of rice at different growth stages. Reference evapo-transpiration was estimated using temperature and radiation data (Hargreaves and Samani, 1985) and crop co-efficient ($K_c$) value at different growth stage of rice was used as suggested by Allen et al. (1998). Total water used during the crop season was categorized into green water (water used from rainfall) and blue water (water used from irrigation) based on the calculated effective rainfall during the crop season. From these data sources, water productivity (t/$m^3$ or INR/$m^3$) and water use efficiency (WUE) were calculated.

Water productivity is generally defined as crop yield per cubic metre of water consumption, including 'green' water (effective rainfall) for rain-fed areas and both 'green' water and 'blue' water (diverted water from water systems) for irrigated areas. The detailed water used and its productivity parameters are presented in Table 6.4.

**Table 6.4 :** Water and water productivity parameters for rice under *Jhola* systems

| Parameter | Season *Kharif* | *Summer* |
|---|---|---|
| Effective rainfall (mm) | 550.5 | 135.2 |
| Irrigated water (mm) | | 558.2 |
| Net cumulative water used (CWU) (mm/ha) | 550.5 | 693.4 |
| Total CWU ($m^3$/ha) | 5505.0 | 6934.1 |
| From rain (Green Water-$m^3$/ha) | 5505.0 | 1352.0 |
| From irrigation (Blue Water-$m^3$/ha) | 0.0 | 5582.1 |
| Green CWU (%) | 100.0 | 19.5 |
| Blue CWU (%) | 0.0 | 80.5 |
| Grain yield (kg/ha) | 2580.0 | 2850.0 |
| Water foot print (Green + Blue) ($m^3$/t) | 2133.7 | 2433.0 |
| Water productivity (kg/$m^{3)}$ | 0.5 | 0.4 |
| Water productivity (INR/$m^3$) (MSP@ Rs.1450/q) | 6.8 | 6.0 |
| WUE (kg/ha-mm) | 4.9 | 4.1 |

The calculated effective rainfall during *kharif* and summer season were 550.5 and 135.2 mm, respectively. Irrigation (water diverted from stream) used only during summer season (558.2 mm). The share of green water during *kharif* and summer rice crop was 100% and 19.5%, respectively. Water foot print during summer was higher (2433 $m^3$/t) compared to *kharif* season (2134 $m^3$/t) with 16% less during the *kharif* season. Water productivity was slightly higher in *kharif* (0.5 kg/$m^3$, Rs. 6.8/ $m^3$) than summer rice (0.4 kg/$m^3$, Rs. 6.0/$m^3$). Similarly, WUE was also higher in *kharif* (4.9 kg/ha-mm) by 19.5% compared to summer rice (4.1 kg/ha-mm).

# 7. Conclusions and Policy Implications

Paddy constitutes a significant component of major staple food in Koraput district. In this tribal dominated district, paddy is cultivated across a range of agro-ecosystem, including upland and lowland, irrigated and rain-fed landscapes, occupying 55% of total cultivated land. Lowland paddy cultivation is practiced mostly in the valleys of the hilly tracts, locally known as *Jhola* land. This land systems are modified stream beds found on or along the stream. This *Jhola* land systems can be compared with inland valley wetlands, and perhaps best defined in relation to the Eastern Ghats region of Odisha. *Jhola* land occur along the lower order streams or the upper reaches of river systems. These land comprise the watersheds of drainage axes in which seepage and runoff from adjacent upland converge. Unlike upland (*Donger, Pada, Beda, Saria*) which experience water scarcity, *Jhola* land have a favorable hydrological condition that ensures that water is at, or near, the surface for most of the year. Therefore, this land systems have a high potential for agricultural development in comparison to adjacent upland, which is under threat of rapid degradation.

The region being one of the highest rice producing belt in Asia needs to be paid attention for sustainable production through scientific management, which may explore means to wean away the tribals from shifting cultivation to settled agriculture. Further, it is observed that sediments brought down the hill by floods during monsoon and partially deposited in these valley land which are supposed to alter the physical properties and nutrient status of the *Jhola* land soils. Keeping this in view, this study was carried out to know the spatial extent of *Jhola* land areas in Koraput district along with its resource use efficiency. The following conclusions are drawn from this study

- In Koraput district, 187.6 sq. km area is under *Jhola* land systems, having mono-crop of paddy, covering 10 blocks of the district.
- These *Jhola* land systems are modified stream beds, occur at elevation of 700m or more above the msl, and 2$^{nd}$ and 3$^{rd}$ order streams mostly contribute origin of the *Jhola* land systems.
- The nutrient status of *Jhola* land systems indicates that they are low in N, medium in P, and there is no trend with respect to availability of K.With respect to water quality, it is good for both irrigation and drinking purpose.
- The soils of *Jhola* land is acidic in nature.
- In *Jhola* land rice production system the renewable and non-renewable energy inputs account for 71.5% and 28.5% of input energy, respectively.
- The Global Warming Potential of rice cultivation under *Jhola* land production system is 610.8 kg $CO_2$ Equivalent/ha, and attributed to low external inputs in the rice production system.
- The share of green water during *kharif* and summer rice is 100% and 19.5%, respectively.
- Water foot print during summer is 16% higher than that of *kharif* season.
- Water productivity is slightly higher in *kharif* than summer rice.
- Water Use Efficiency is also 19.5 % higher in *kharif* than summer

## 7.1 Policy Implications

- As this land systems are having good moisture status throughout the year, the land can be converted from mono-cropped area to double cropped area.
- Vegetables can be opted in the upper and middle part of *Jhola* land during post monsoon season.
- Package of practices for suitable vegetable cultivation in the *Jhola* land during rabi season can be introduced and promoted by state government officials.
- In the lower *Jhola* land, Pisciculture along with paddy can be carried out.
- As main problem of this land is breaching of bunds and siltation or sand deposit on the fields during heavy rain, earthen bunds can be replaced with semi-mechanical bunds (earthen cum stone bunds) and vegetative barrier like sambuta grass can be raised on the bund.
- To prevent siltation problem in the *Jhola* land, there is a need of afforestation in the catchment area.

- Stream bank protection is a must in medium to deep *Jhola* streams to prevent encroachment of nala to the agricultural fields
- Compartmental bunds are to be strengthened by planting submuta grass.
- Glyricidia can be incorporated in the field for enhancing nutrient status.
- Blue green algae cultivation can be opted in the
- Anti-lodging paddy variety can be introduced in the *Jhola* land.
- Indigenous paddy variety can be promoted in the *Jhola* land during *kharif* season.
- *Jhola* khundi technology to be promoted and upscaled for cultivation of vegetables during *rabi* and summer season.
- Catchment areas of the *Jhola* land systems are to be conserved and protected with scientific land use and land management practices for sustainability of water resources in the *Jhola* system.
- Integrated farming is the best options for profitability and efficient use of resources and this need to be promoted.

## 7.2 Future Research Gaps

- Carbon sequestration potential of *Jhola* land can be studied.
- Impact of climate change on availability of *Jhola* water can be studied.
- Isotopic study of *Jhola* water can be made to know the source and sink of *Jhola* water.
- The effect of catchment land uses on the water quality of *Jhola* land systems need to be studied.

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# 9. Acronyms and Abbreviations

| | | |
|---|---|---|
| $^{o}$ | : | Degree |
| , | : | Minute |
| ,, | : | Second |
| % | : | Percent |
| ASTER | : | Advanced Space-borne Thermal Emission and Reflection Radiometer |
| C | : | Clay |
| $CH_4$ | : | Methane |
| $CO_2$ | : | Carbon dioxide |
| CWU | : | Consumptive Water Use |
| DEM | : | Digital Elevation Model |
| dS | : | Deci Simen |
| EC | : | Electrical Conductivity |
| EGHLR | : | Eastern Ghats High Land Region |
| ERDAS | : | Earth Resources Digital Analysis System |
| ESP | : | Exchangeable Sodium Percentage |
| $ET_0$ | : | Reference evapotranspiration |
| FCC | : | False Colour Composite |
| FYM | : | Farm Yard Manure |
| GHG | : | Green House Gas |
| GIS | : | Geographical Information System |
| GR | : | Green Ratio |
| GSI | : | Geological Survey of India |
| GWP | : | Global Warming Potential |
| h | : | Hour |
| ha | : | Hectre |
| IISWC | : | Indian Institute of Soil and Water Conservation |
| INR | : | Indian Rupee |
| IPCC | : | Inter-govenermental Pannel for Climate Change |
| IRS | : | Indian Remote Sensing |
| K | : | Potassium |
| Kc | : | Crop Co-efficient |
| kg | : | Kilogram |
| km | : | Kilometer |
| L | : | Loam |
| LISS | : | Linear Imaging Self Scanner |
| LSI | : | Langelier Saturation Index |
| M | : | Million |
| m | : | Meter |
| MJ | : | Mega Joule |
| msl | : | Mean Sea Level |
| MSP | | Minimum Support Price |
| N | : | Nitrogen |
| NDVI | : | Normalized Difference Vegetation Index |
| NRSA | : | National Remote Sensing Agency |
| $^{o}$C | : | Degree Celcius |
| OC | : | Organic Carbon |
| ORSAC | : | Orissa Space Application Centre |
| OWDM | : | Odisha Watershed Development Mission |
| P | : | Phosphorous |
| pH | : | Potential of Hydrogen |
| PI | : | Permeability Index |
| ppm | : | parts per million |
| q | : | Quintal |
| RS | : | Remote Sensing |
| RSC | : | Residual Sodium Carbonate |
| RVI | : | Ratio Vegetation Index |
| S | : | Sandy |
| SAR | : | Sodium Adsorption Ratio |
| SC | : | Scheduled Caste |
| SD | : | Standard Deviation |
| Si | : | Silt |
| SOI | : | Survey of India |
| sq | : | Square |
| ST | : | Scheduled Tribe |
| t | : | ton |
| TDS | : | Total Dissolved Solid |
| TGA | : | Total Geographical Area |
| WUE | : | Water Use Efficiency |
| y | : | Year |

# 10. Annexures

## Annexure - I

### Proceedings of Interaction Work-shop on *Jhola* Land Utilization

One day interaction workshop on "*Jhola Land Utilization*" was organized by Indian Institute of Soil and Water Conservation (IISWC), Research Centre, Sunabeda, Koraput, at Conference hall of the Research Centre on 22nd April 2015. The objective of the programme was to discuss, collect information on several relevant issues related to *Jhola* land cultivation.

In the workshop, a total of 23 farmers and farm women from six villages (Chalanput, Patraput, Podagada, Mukhibidai, Badabadigaon, Malipungar) of Semiliguda block, Koraput district were participated. Dr M. Madhu, Head, RC, Sunabeda, Dr Ch. J. Dash, Scientist (SWCE), Mr. M.K. Meena, Scientist (Agricultural Economics), Mr. G.B. Naik (Sr. Technical Officer) and Mr. G.W. Barla (Sr. Technical Assistant) were interacted with the farmers.

Relevant issues of *Jhola* land systems like present cultivation practices in *Jhola* land, problems related to *Jhola* land cultivation, source of water to *Jhol*a systems, viable options for development of these highly productivity land, and scientific management of *Jhola* land were discussed.

- *Jhola* land are the land, continuously fed with the stream water.

- These are the most fertile land among arable land, however cultivated with only paddy throughout the year.

- Iron toxicity along with sediment deposition during rainy season is the major problem of the *Jhola* land.

The water of *Jhola* land can be diverted and used in the adjoining upland.

**Photo 1:** Presentation and interaction during the workshop on *Jhola* land utilization

## Annexure - II

## SELECTED PHOTOS

A typical *Jhola* system

Flooding in the *Jhola* land during *kharif* season

Nursery in the *Jhola* land

Deposition of silt in *Jhola* land

Transplanting in *Jhola* land

Vegetative barrier on the bund to check erosion

*Jhola* kundi in *Jhola* system

Collection of Soil sample

Use of *Jhola* kundi water for vegetable cultivation

Collection of water sample


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