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Agroecosystem Sustainability in Forest Dependent Tribal Villages in Odisha, Eastern India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present study was carried out in Niyamgiri hills inhabited by primitive Dongaria tribes in Odisha to assess present state of socioeconomic components of village and efficiency and viability of production systems at the current level of natural resource dependency and to find out the linkage between human community and forest ecosystem. The study area comprises of eight villages where human population varies from 83 to 312 in uphill villages and 76 to 150 in foothill villages. The cultivated area ranges from 3.37% to 18.85% of the total village geographical area with per capita cultivated area 0.117 to 0.329 ha.. The quality of forest has been affected due to absolute dependency on resources which calls for taking appropriate step to enhance forest productivity. All villages depend on rain fed agriculture, natural stream water is used to cultivate paddy in valleys, shifting (Podu) cultivation practiced in uphill areas, mid hill orchards below the Podu area and home garden adjoining habitation. Cereals, pulses and oil seeds are grown together in Podu areas. Maize is a major cereal as staple food grown in uphill villages. The village productivity of Millets, legumes and paddy is much lower than other settled agriculture areas of the state. The home

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garden areas are grown with vegetables and cereals especially for domestic use. However, vegetables like Tomato, Brinjal, Bin, Sweet Potato, Chilly from foothill villages are marketed. Home garden provides variety of requirements to the tribal community round the year. The production of agriculture sub-system is not sufficient to meet the food requirement of villages and rice distributed to villagers meet this gap. However, crops grown as horticulture products (Jackfruit, Pine apple, Banana, Orange, Mango) and a few Millet crops in the uphill villages like minor Millets, are exported to markets for earning money as these are only assets recorded as high energy valued products. Odisha Millet Mission (OMM) may need to provide interventions to these villages with modern approach to increase Millet productivity including improvements in seed quality and health condition of the tribal community. To ensure sustainability of the traditional cultivation and livelihood system, involving the people of these villages in forest-based activities other than agriculture will lead to protecting the indigenous biodiversity of this region.

Keywords: Agriculture; millet; forest; livelihood options; niyamgiri; Odisha, podu cultivation; sustainability; tribal.

1. INTRODUCTION

The people living in surroundings of the natural protected areas depend on these Ecosystems for their livelihood and ecosystem services including water, fuel, fodder and other forest produce. The people inhabiting in these zones and surroundings are experiencing decline in resource value [1], so their access to various components of natural resources is becoming a limiting factor to survive. The tribal villages near forests mainly perform their activities by recycling resources within the system [2,3,4,5] The traditional practices of ethnic human population which was a sustainable way of living with ecosystem are being modified due to resource depletion and imbibing modern way of livings. This defeats the goals of biodiversity conservation in natural forest ecosystems as demand driven society will cause depletion and extinction of living natural species. Therefore, changing consumption and agricultural cultivation patterns now demands integrating protected area management with development projects by ensuring an effective participation of people in the management process [6-8]. The tribal people living in and around forest areas are to adapt themselves to environmental pressure associated with market driven natural resource exploitation [9]. Therefore, these interactions must address the sustainable way of the functioning of natural ecosystems [10]. The study of interrelations between a tribal village settlement and its natural environment requires an interdisciplinary approach. The livelihood strategies need to be diversified with enhanced education on real time weather information system [11]. This is because social systems reproduce themselves not only culturally and socially, but also physically by constantly exchanging energy and material with their natural environment and with other socio-economic systems.

Traditional agriculture generally is practiced in organic way and has inbuilt mechanism to optimize their use and their subsistence life styles. We can assess the subsistence economy and market and lifestyle changes by input-output analysis in traditional forest dependent villages are in understanding the village ecosystem functions [12-14]. The present study was carried out in Niyamgiri hills inhabited by primitive Dongariya tribes in Odisha to assess socioeconomic components of village and efficiency of production systems and viability at the current level of natural resource dependency and to find out the linkage between human community and forest ecosystem and suggest sustainable model. Thus, this case study aims at gathering information on agro-ecosystem practices functioning around Niyamgiri Forests and to suggest how conservation objectives can be achieved making village agroecosystem practices sync with ecological requirements.

2. MATERIALS AND METHODS

Niyamgiri forest is one of the most important ecological habitats in southern Odisha.It lies between$83^0$17’ to $83^0$29' E long and $19^0$22’ to 19^{0-} 42’N lat. Administrative jurisdiction covers three blocks (Muniguda, Bissam-cuttack, K. Singhpur) of Rayagada district and one block (Lanjigarh) of Kalahandi district. Most part of the forest remains un-surveyed due to inaccessibility. Only few Reserve Forest (RF) and Proposed Reserve Forest (PRF) exist in the Niyamgiri Hill Range covering 125.86 sq km. (Table 2). Most of the forest area remained un-surveyed.

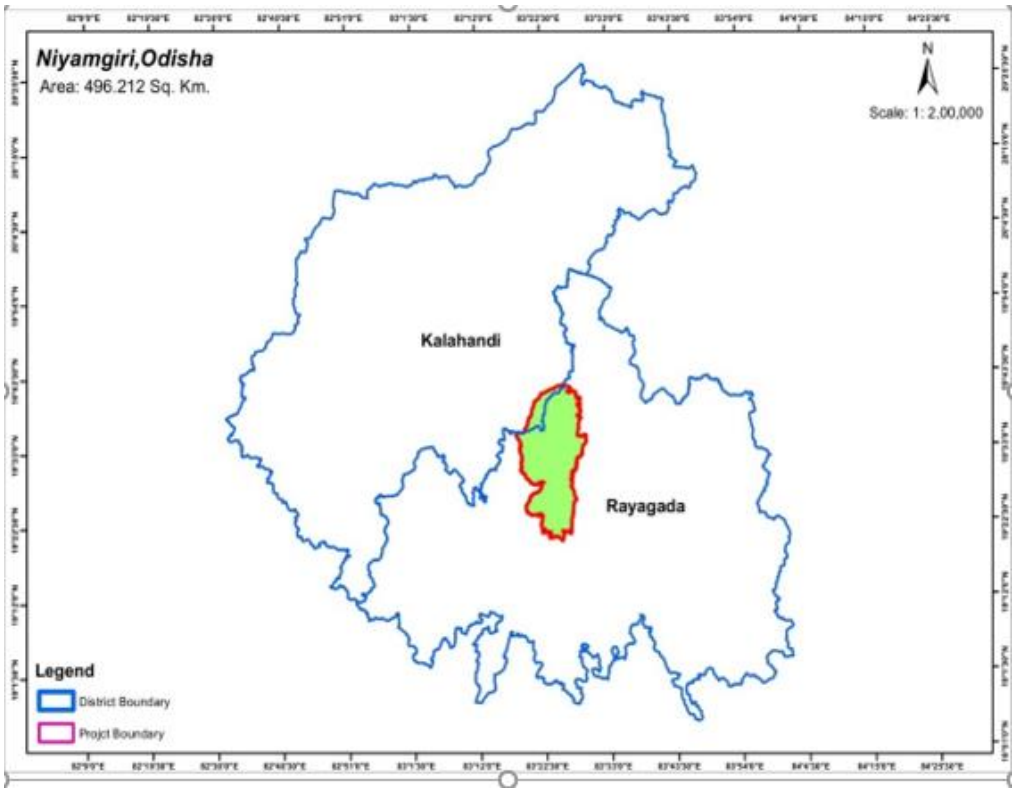

Plate 1. Location of Niyamgiri Hills in the District of Rayagada and Kalahandi, Odisha India

Varied topography with continuous valleys and ridges, and unbroken mantle of forest supports very rich bio-diversity involving topical and sub-topical species. It is the cradle of major rivers of Rayagada district with Bansadhara in North and Nagabali in South which flows to the Bay of Bengal through Andhra Pradesh, Niyamgiri Hill Forests in elongated in North-South direction (ca 36 km) with average width of about 15 km and encompasses about 496 sq km area.

The altitudinal variation is from 400m mean sea level (msl) to 1516m msl which is responsible for varied vegetation, higher rainfall, and cooler micro-climate with perennial streams. Niyamgiri hill range is an extensive area with degraded Sal forest interrupted by practices of shifting (*Podu*) cultivation near the habitation areas. Inhabitants in the range are *Kandha* tribe namely *'Dongria Kandha*'- a primitive tribal group settled near perennial streams in high altitude areas (600-700m msl). In the region microclimate effect is clearly revealed with cooler atmosphere, more rainfall than adjoining area and rich biodiversity. The settlements are connected by difficult terrain footpaths. All weather roads is a recent development to peripheral villages otherwise the vast tract of land is almost virgin. Shifting cultivation provides food and fodder to the ecosystem people and forest provide additional support with tubers, fruits, leafy vegetables besides fuel wood, housing materials, agriculture implement and grazing land. Although Niyamgiri Hill Ranges extend in four blocks, the Bissam Cuttack block is selected for the present study because the villages are located at approachable distance. Four village settlements at higher elevation inside Niyamgiri Forest are selected for the study of Agro-ecosystems. Another four village settlements selected at the foot hill of Niyamgiri out of which two are closer to market place (urban area) and two are little away from urban area. The village settlements are:

Village inside Niyamgiri Hill Forest at higher altitude.	1. Patlamba 2. Rodanga 3. Khajuri 4. Gortali
Villages outside Niyamgiri at the foot hills, away from market place	5. Majhihalma 6. Bhaliabhatta
Villages outside Niyamgiri at the foot hills, nearer to market place	7. D. Kumbharbadi 8. Papikhunti

Niyamgiri hill ranges experiences monsoon climate, from mid-May to mid-October which is

more than normal monsoon period of three months. The average rainfall of the district varies from 1013.66 mm to 1491.4 mm over 5 years i.e. 2009 to 2013. The tropical monsoon accounts for mainly total annual rainfall of 1100-1500 mm with concentration in rainy season (July to September). The temperature variation of the district ranges between 6.5℃ and 30℃ (data average 2009 to 2013) and the relative humidity varies from 40% (March) to 85% (July) [15]. Most of the streams are perennial in nature and the inhabitants use the water for domestic purpose and irrigation. The forest vegetation is of miscellaneous nature with intermittent Sal forest with its associates. The practice and traditional agriculture is prehistoric The villages in and around Niyamgiri Hill Range derive their livelihood from forest resources. The intense inter-dependency of Agro-ecosystem and Forest eco-system has led to both ecological and economic erosion in these ecosystems.

2.1 Methods of Study

The socio-economic data and ecological parameters of the eight villages were collected through questionnaire-cum-schedule method following Reddy [16], Singh and Singh [17], Nayak et al. [4] and Sahoo [18]. Four villages were situated inside Niyamgiri Hill Forest at higher altitude, two villages at the foot hills, away from market place and two villages at the foot hills, nearer to market place. The sampled villages were visited regularly depending on the availability of the inhabitants and information was collected by interviewing the family head about their occupation, source of income, materials used in day to day life and construction of houses, cultivation and Agro-products market and sale of available surplus product, after self-use, etc. Sample weighing of humans, animals and materials was done in the field. The data collection continued for reverification in the selected villages from year 2010 to 2015 by repeated visits and interview as needed. The human population was calculated from the total family members of the villages. The above ground biomass of crops grown in shifting cultivation area, home garden and valley area were estimated in the field at the time of harvest. The individual biomass production was added to get the total village biomass production (t ha^{-1}). The productivity was calculated for the total production of the village crop wise and divided over the cultivated area to get average productivity of the village. The information of sale and purchase of different commodities by villagers was recorded. The food consumption was calculated depending on the total production for Agriculture, Forest animal husbandry etc. excluding the products sold in weekly market or village itself as surplus only. The food grain, vegetable etc. purchased from weekly market or Public Distribution System (PDS) are added to the quantity consumed. The crop residue left in the field was collected in a sample area and weighed to assess the total residue left in the fields.

3. RESULTS

The details of geographical area of the eight villages under study are given in Figs. 1-8 with the break-up of components under housing and cultivation (Home garden, shifting cultivation and valley cultivation). The villages are widely separated from each other and boundaries are demarcated by the hilly topography and vegetation. For shifting cultivation and collection of minor forest produce, the forests beyond the village boundary are used by villagers. Per capita cultivated area varies from 0.117 ha. (Patlamba) to 0.329 ha. (D.Kumbharbadi). Forest area is utilized for shifting cultivation and home garden. Paddy cultivation is practiced in one upper hill village (Rhodanga) and three-foot hill villages (Majhihalma, Bhaliabhatta and D. Kumbharabadi) (Figs. 1 to 8). Shifting cultivation is prominent in four villages located in upper hill area (i.e. Patlamba, Rhodanga, Khajuriand, Gortali). Human Population dynamics in villages indicate that average family size varies from 3.8 to 5.2 (Table.7). The literacy rate varies widely from 4.8% in Patlamba to 72% in D. Kumbharbadi. Elder persons above age group of above 40 years are totally illiterate in uphill villages, however the adults with age group 25-30yrs have some education. The topography plays a major role in the land use with easy gradient slopes with soil cover are mostly used for raising crops under the shifting cultivation. It is always a poly culture locally known as “Dongar” cultivation of all cereals, pulses, oil seeds type complex cropping traditional practice with ecological and economic advantages in rain-fed condition. Other land use category is the valley area cultivation known as “Gudia” or “Padar” which is mostly used for Ginger and Turmeric and some fruit plants surrounding the field or house. The land is mostly used for different cash crops like Bananas, Orange, Mango, Litchi, Jackfruit etc. The third land use category cultivation is the Nala-beds / aquatic

areas with perennial stream flow of water mostly used for paddy. The villages situated at low elevation in the periphery of Niyamgiri practice paddy cultivation using stream water in very small patches. High rainfall in these areas sometimes lead to speedy flow in Nala-beds washing all crops. Thus, three major categories of land are available for agricultural use. The home-stead village areas are very small with compact houses in rows facing each other with common place. The aquatic area is only streams which are mostly perennial and major common property resource (CPR) is forest land and the uncultivated area.

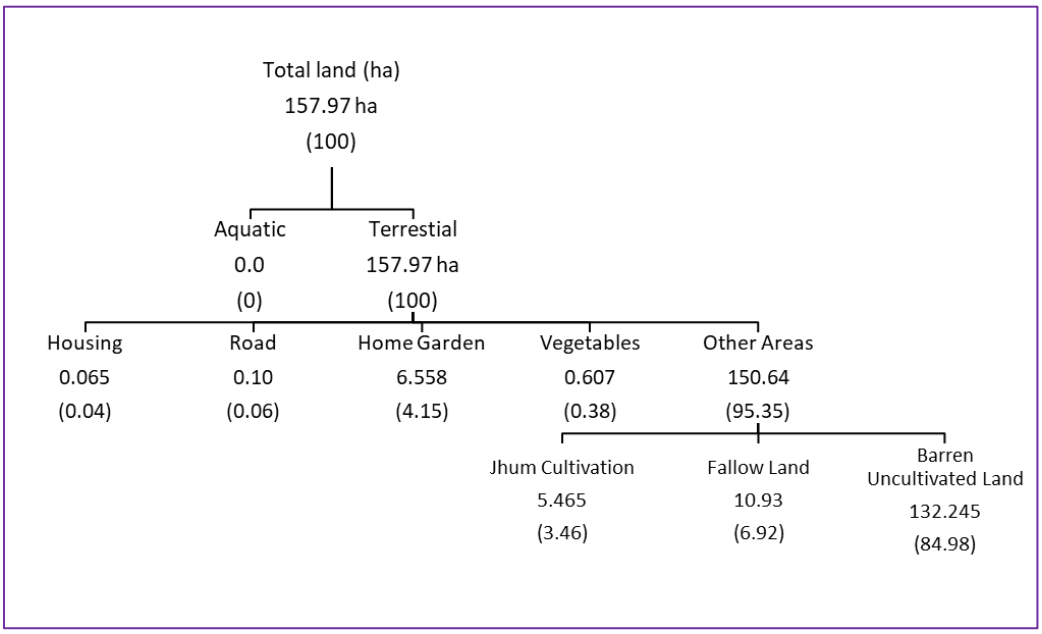

Fig. 1. Land use pattern of village Patlamba. Data in parenthesis indicates the percentage of contribution

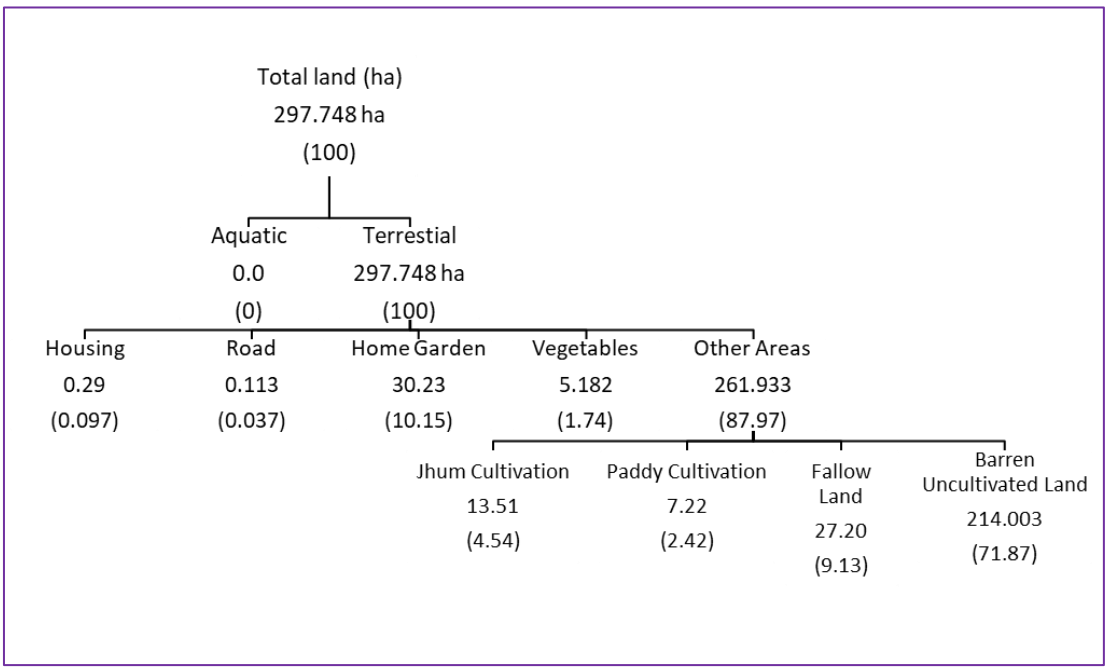

Fig. 2. land use pattern of village Rodanga. Data in parenthesis indicates the percentage of contribution

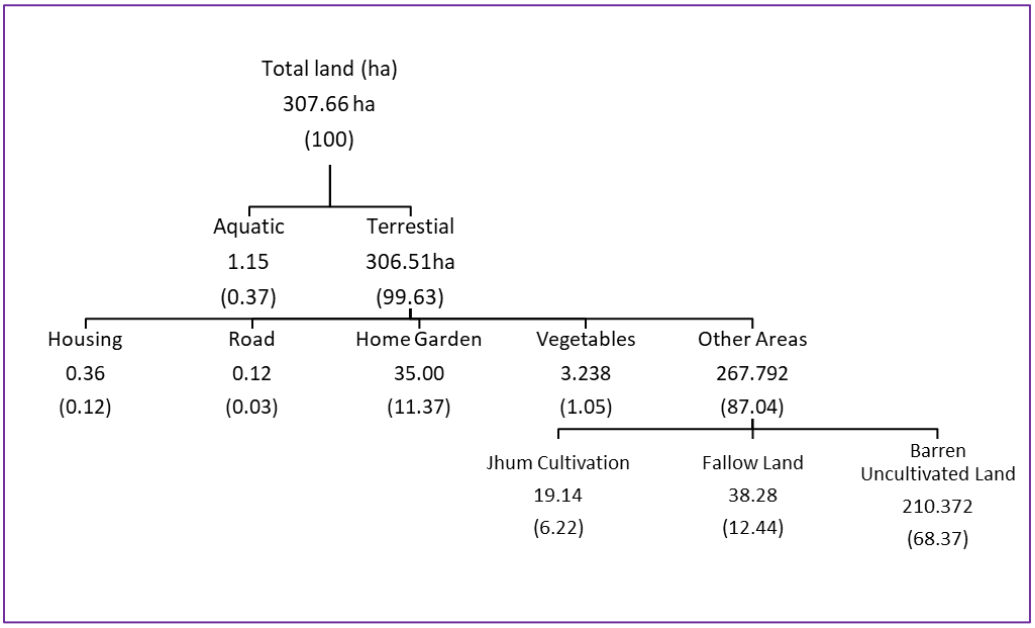

Fig. 1. land use pattern of village Khajuri. Data in parenthesis indicates the percentage of contribution

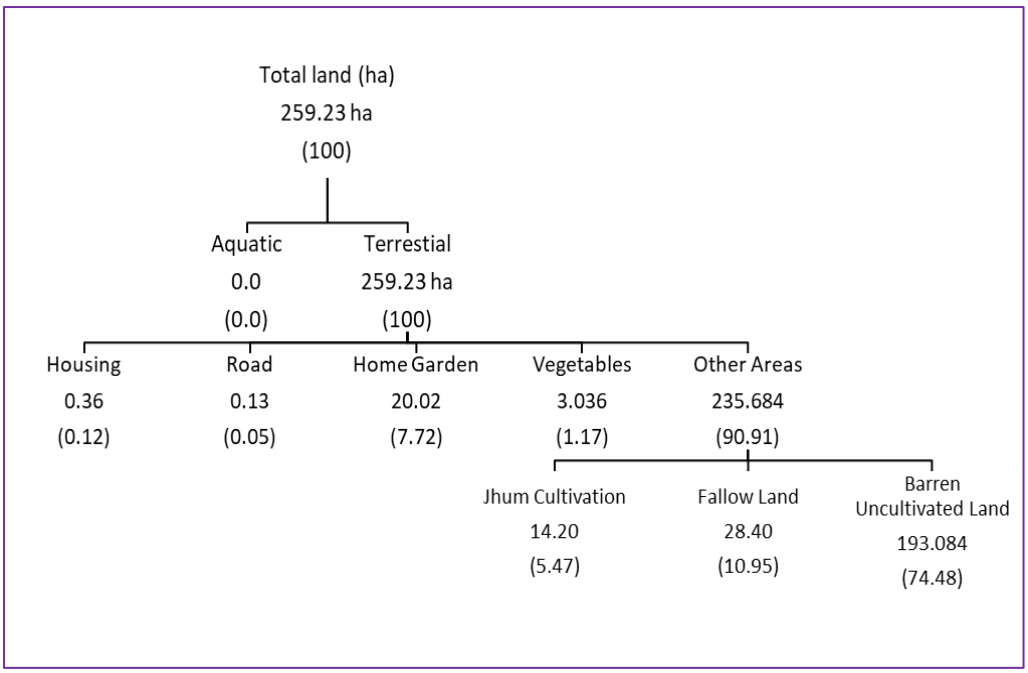

Fig. 2. Graphical representation of land use pattern of village Gortali. Data in parenthesis indicates the percentage of contribution

3.1 Agro-Ecosystem and Village Ecosystem Function

3.1.1 Cropping pattern

The cropping pattern is regulated by nature as per the annual seasonal variation of rainfall and temperature. Almost all cultivation is rain fed in nature and accordingly land preparation starts in summer, cultural operation continues in rain and harvest of crop starts at beginning of winter. In these three seasons, about 9 months a year, people remain busy in the field. The cropping pattern of different crops is

detailed in Table-1 which is almost similar for all villages. The uphill villages cultivate different types of cereals which is unique for this locality.

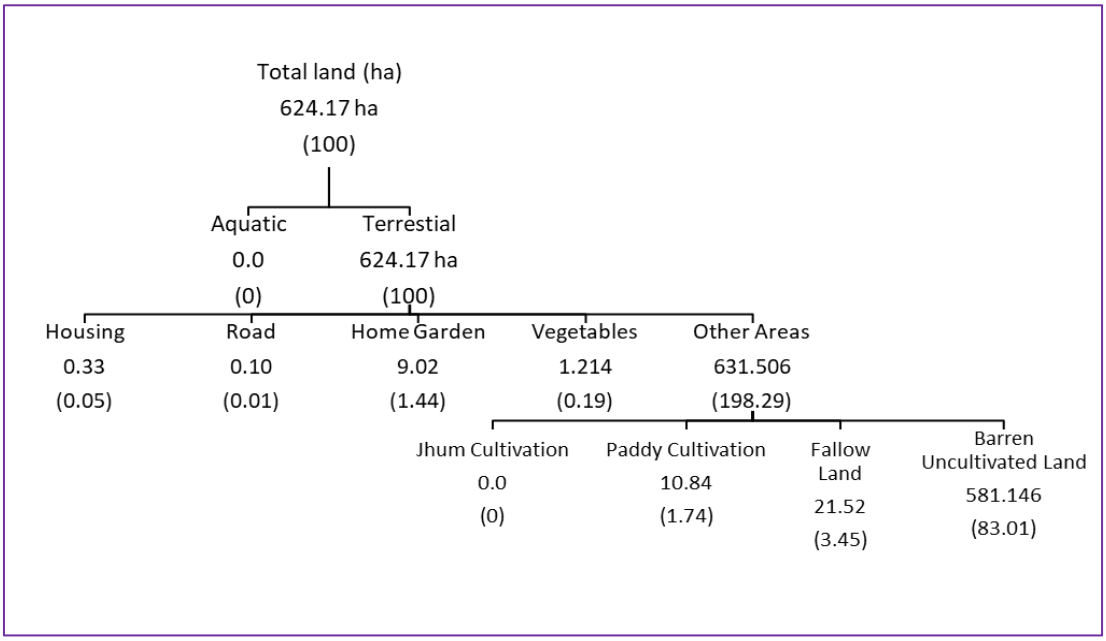

Fig. 3.Graphical representation of land use pattern of village Majhihalma. Data in parenthesis indicates the percentage of contribution

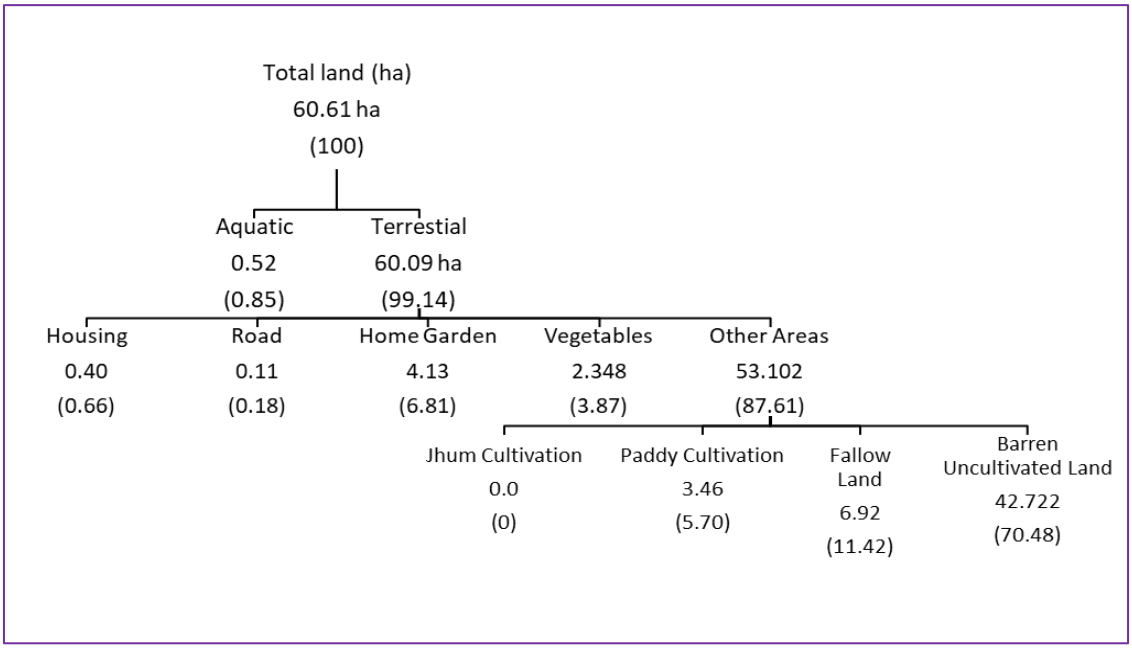

Fig. 4.Graphical representation of land use pattern of village Bhaliabhatta. Data in parenthesis indicates the percentage of contribution

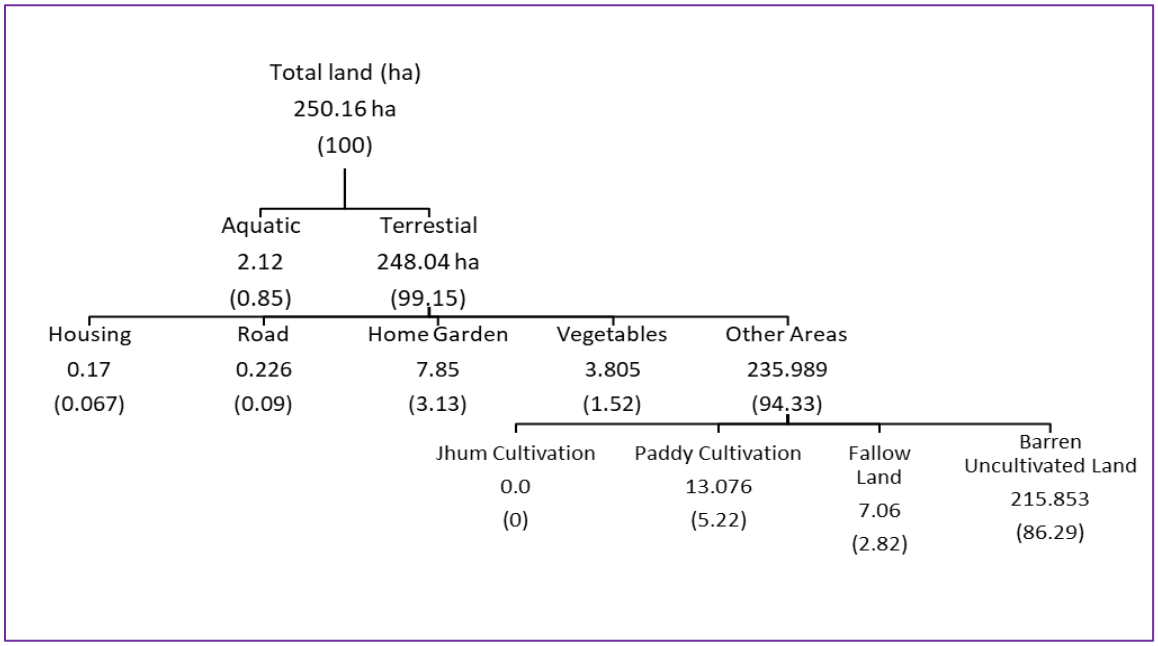

Fig. 5.Graphical representation of land use pattern of village D. Kumbharbadi. Data in parenthesis indicates the percentage of contribution

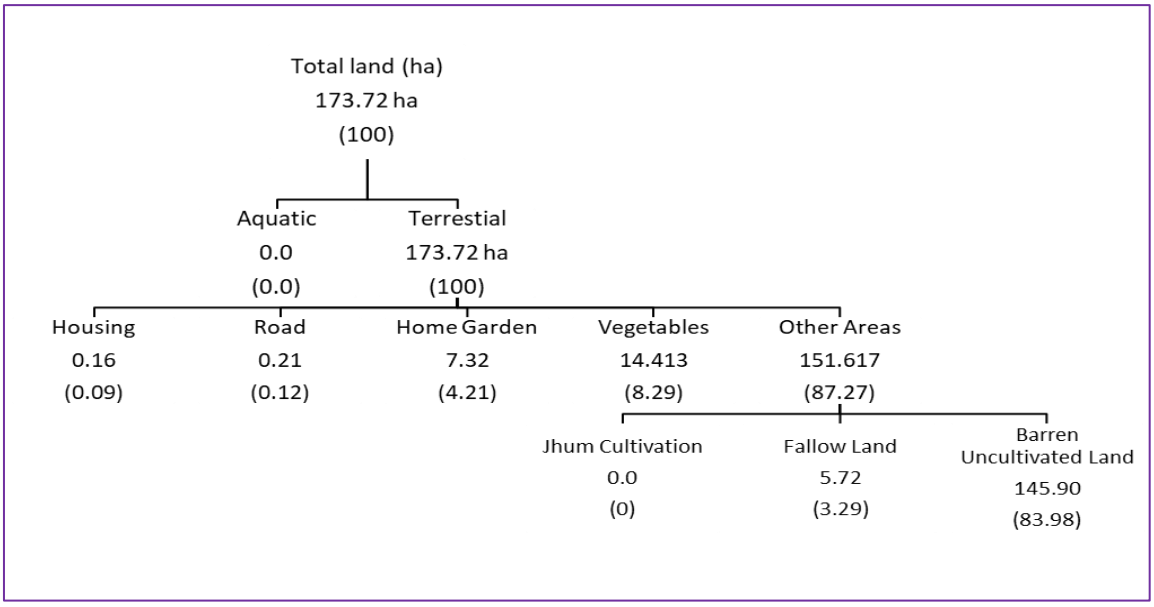

Fig. 6. Land use pattern of village Papikhunti. Data in parenthesis indicates the percentage of contribution

3.1.2 Area under cultivation and crop yield

The Agro ecosystem productivity of these villages can be grouped into four categories on the basis of the production of different crops and their geographical location viz., *Podu* cultivation, Mid-hill orchards, Home-garden, and Valley cultivation areas. Since all the villages are more or less associated with hills, the classification is based on the topography. Area of different crops is shown in Table 2. The primary productivity (yield) of these villages depends mostly on natural factors. The biomass and productivity (yield) of crops in the villages were assessed for various category of land uses. Productivity refers to the production per unit area over time and the biomass refers to the weight of organic matter produced in the crop. Present study involves the

estimation of biomass and net primary production (yield) of these tribal village Agro-ecosystem. Agricultural Crop Productivity of the each of Village Ecosystem for the year 2010-11 is given in Table 3.

3.1.3 Podu cultivation

Shifting cultivation commonly known as Podu cultivation is a prevalent practice in hilly forest areas, mostly an adopted agriculture system by the tribal community. The areas of individual household's Podu cultivation were ascertained by sample field verification of each village. The village-wise area under different crops is given in Table-2. Podu cultivation is prominent in uphill villages of Niyamgiri, whereas it is rarely practised in foothill villages. Here also, the Dongaria Tribe practice Podu cultivation in uphill areas for the production of different agriculture crops. The cereals, pulses and oil seeds are grown in mixed cultivation practice to meet the

Table 1. Cropping Pattern and their seasonal distribution in Niyamgiri Hill study area

Crop		Sowing season	Harvest season	Village
CEREALS				
1	Paddy (*Oryza sativa*)	Jun -July	Nov - Dec	R, M, B, D
2	Maize (*Zea mays*)	May - June	Sept - Oct	P, R, K, G, B, M, D, H
3	Finger Millet (*Eleusine corocana*) MANDIA	Jun -July	Sept - Oct	P, R, K, G, B, M, D, H
4	Pearl Millet (*Pennesetum typhoides*) GHANTIA	Jun -July	Nov - Dec	P, R, K, G, B, M, D, H
5	Common Millet (*Panicum paludosum*) KANGU	May - June	Nov - Dec	P, R, K, G, B, M, D, H
6	Barnyard Millet (*Echinochloa conlonum*) KOSHALA	Jun -July	Nov - Dec	P, R, K, G, B, M, D, H
LEGUME				
1	Red Gram (*Cajanus cajan*) KANDULA	Jun -July	Jan - Feb	P, R, K, G, B, M, D, H
2	Jhudanga (*Vigna unguiculata*)	Jun -July	Oct - Nov	P, R, K, G, B, M, D
3	Katinga (*Vigna* sps)	Jun -July	Sept - Oct	PRKG
OILSEED				
1	Castor (*Ricinus comunis*) JADA	Jun -July	Feb - March	R, K, G
2	Niger (*Guizotia obyssinica*)	Jun -July	Feb - March	R, K, B, M, D, H
3	Rasi (*Sesamum indicum*)	Sept - Oct	Feb - March	H
	VEGETABLES			
1	Brinjal (*Solanum melanogena*)	Aug -Sept	Nov - Dec	P, R, K, G, B, M, D, H
2	Tomato (*Lycopersium esculentum*)	Aug -Sept	Nov - Dec	P, R, K, G, B, M, D, H
3	Lady Finger (*Hibiscus esculentus*)	Aug -Sept	Nov - Dec	B, M, D, H
4	Simba (*Dolichus* sp)	Aug -Sept	Nov - Dec	P, R, K, G, B, M, D, H
	CASH CROPS			
1	Cotton (*Gossypium hirsutum*)	June - July	Nov - Dec	H
2	Tobacco (*Nicotiana tabacum*)	June - July	Nov - Dec	M, B, D, H
3	Turmeric (*Curcuma longa*)	April -May	Jan - Feb	P, R, K, G
4	Ginger (*Zingiber officinale*)	April -May	Nov - Dec	P, R, K, G
	FRUITS			
1	Jack Fruit (*Artocarpus integrifolia*)		Green (Feb - March) June-July	P, R, K, G, M, B, D, H
2	Mango (*Mangifera indica*)		May-June	P, R, K, G
3	Pine Apple (*Ananas sativa*)		June-July	P, R, K, G
4	Orange (*Citrus sinensis*)		Sept-Oct	R, K, G

Note: P- Patlamba, R- Rodang ,K- Khajuri,G- Gortali,M- Majhihalma, B- Bhaliabhatta, D- D. Kumbharbhadi, H- Papikhunti

Table 2. Area Under Cultivation of Different Crops (ha) in the Village Under Study During

	P	R	K	G	M	B	D	H
Podu cultivation (Up Hill)								
Finger Millet (Mandia)	5.465	13.522	19.149	14.21	9.028	4.129	7.854	7.328
Pearl Millet (Ghantia)	5.465	13.522	19.149	14.21	-	-	-	-
Common Millet (Kangu)	5.465	13.522	19.149	14.21	-	-	-	-
Barnyard Millet (Koshala	5.465	13.522	19.149	14.21	-	-	-	-
Redgram(Kandula)	5.465	13.522	19.149	14.21	-	-	-	-
Jhudang	5.465	13.522	19.149	14.21	-	-	-	-
Kating	5.465	13.522	19.149	14.21	-	-	-	-
Caster seed	5.465	13.522	19.149	14.21	-	-	-	-
Niger	5.465	13.522	19.149	14.21	-	-	-	-
Rasi	5.465	13.522	19.149	14.21	-	-	-	-
Mid Hill (Orchard)								
Zinger	0.1	10.1	10.9	6.8	-	-	-	-
Turmeric	1.0	11.56	7.20	4.40	-	-	-	-
Orange	0.00	2.13	1.05	1.0	-	-	-	-
Mango	1.60	3.24	16.92	7.8	-	-	-	-
Pine Apple	1.6	3.24	16.92	7.81	-	-	-	-
Jack Fruit	0.4	0.80	0.61	0.40	0.10	0.04	0.10	0.06
Home Garden								
Vegetables	0.61	5.18	3.24	3.04	8.06	3.4	7.11	15.2
Valley								
Paddy	-	7.22	-	-	10.9	3.46	13.1	-
Maize	0.566	1.235	10.809	9.514	8.016	4.574	4.777	0.554
NB-Cereals, legumes and oilseeds grown in same land								
NB-Mango and Pine apple are grown in same land								

Note: P- Patlamba, R- Rodang ,K- Khajuri,G- Gortali, M- Majhihalma, B- Bhaliabhatta, D- D. Kumbharbhadi, H- Papikhunti

food requirement of the family. The common crops are Finger Millet (Mandia), Pearl Millet (Ghantia), Common Millet (Kangu), Barnyard Millet (Koshala), Redgram (Kandula), Jhudang, Kating, Caster seed, Niger and Rasi. Higher slope with soil cover areas are selected for the Podu cultivation. Trees including undergrowth are completely cut and burn during summer. Small stumps are uprooted living the big stumps to naturally decay. This process is carried out during February to April i.e. before monsoon. The families occupy different patches for shifting cultivation which is rotated in a three-year cycle. The occupation of shifting cultivation area is almost hereditary, though it has no records in Government revenue or forest department. The extent of cultivation area is taken as per the working members of the family. Sowing is done after first few showers. Pulses like Redgram, Jhudang, Kating and oilseeds of caster are sown in lines at regular interval, whereas other seeds of cereals and oilseeds are broadcasted over the entire area. The watch and ward provision from the wild animals are made by preparing a small hut nearby which continues up to the crop harvest. The cropping pattern and their seasonal distribution is detailed in Table 1 and photographs of plants, fruits seeds of crops grown by villagers are shown in Picture 1 to Picture 10.

3.1.4 Mid-hill cultivation (Orchards)

The forest area below the Podu cultivation area and above the village habitation is cultivated and used for developing different orchards like; Mango, Orange, Jackfruits, etc., with under crops like; Pineapple, Zinger and Turmeric. All these crops are mostly induced practice with the support of Dongaria Kandha Development Agency (DKDA) and other Government Schemes. Annual maintenance of these crops is done by cutting of weed growth and providing mulching to the trees. Zinger is annually harvested and planted, whereas turmeric is harvested in 2nd or 3rd year and planted again during summer. The area of different household is calculated for different villages given in Table 2. All the crops are cash crop which provide good annual income to the uphill villagers. These orchards and under- crops are rarely practised in foothill villages.

Picture 1. Pearl Millet (GHANTIA)

Picture 2. Common Millet (KANGU)

Picture 3. Finger Millet (MANDIA)

Picture 4. Barnyard Millet (KOSHALA)

Picture 5. Grains of Common Millet (KANGU)

Picture 6. Grains of Finger Millet (MANDIA)

Picture 7. De-husked Grains of Barnyard Millet

Picture 8. Grains of Pearl Millet (GHANTIA) (KOSHALA)

Picture 9. Seeds of Vigna species

Picture 10. Seeds of Cajanus cajan

Picture 11. Pineapple Cultivation at Mid-hill Orchards

Picture 12. Jackfruit in Niyamgiri Forest

Picture 13. Mid hill Orchard at Village Khajuri

Picture 14.Vegetable Cultivation at Papikhunti

Picture 15. Turmeric in mid hill Orchard

Picture 16. Paddy cultivation at Rodanga at Village Patlamba

Table 3. Agricultural crop productivity of the uphill village ecosystem

Crop		Patlamba		Rodanga		Khajuri		Gortali	
CEREALS		**P**	**T P**	**P**	**T P**	**P**	**T P**	**P**	**T P**
1	Paddy *(Oriza sativa)*	-	-	2.424	17.5	-	-	-	-
2	Maize *(Zea mays)*	0.220	0.125	0.340	0.420	0.203	2.200	0.184	1.760
3	Finger *Millet (Eleusine corocana) MANDIA*	2.061	11.267	2.194	29.681	2.651	50.770	2.744	39.000
4	Pearl *Millet (Pennesetum typhoides) GHANTIA*	0.381	2.086	0.188	2.550	0.229	4.390	0.322	4.590
5	Common *Millet (Panicum paludosum) KANGU*	2.737	14.960	1.414	19.125	0.549	10.520	0.864	12.280
6	Barnyard *Millet (Echinochloa colonum) KOSHALA*	3.516	19.713	4.465	60.388	3.683	70.534	3.753	53.339
LEGUMES									
1	Red Gram *(Cajanus cajan) KANDULA*	0.826	4.520	0.995	13.464	1.072	20.538	1.236	17.568
2	Jhudanga *(Vigna unguiculata)*	0.269	1.475	0.779	10.540	0.818	15.675	1.350	19.190
3	Katinga *(Vigna sps)*	0.369	2.020	0.331	4.470	0.446	8.551	0.447	6.355
OILSEED									
1	Castor *(Ricinus comunis) JADA*	-	-	0.019	0.259	0.055	1.059	0.032	0.456
2	Niger *(Guizotia obyssinica)*	-	-	0.015	0.059	0.056	0.034	0.000	-
VEGETABLES									
1	Brinjal *(Solanum melanogena)*	0.411	0.05	0.336	1.2	0.296	0.3	0.329	0.2
2	Tomato *(Lycopersicum esculentum)*	0.165	0.08	0.278	0.45	0.292	0.65	0.288	0.7
3	Simba *(Dolichous lablab)*	-	0.035	-	0.075	-	1.895	-	1.43
CASH CROPS									
1	Turmeric *(Curcuma longa)*	0.564	0.548	0.893	10.33	0.842	6.072	0.826	3.42
2	Ginger *(Zingiber officinale)*	0.988	0.12	2.562	25.83	2.547	27.74	2.621	17.83
3	Banana*(Musa paradisiaca) t/ plant*	-	-	0.008	2.37	0.009	2.925	0.0098	1.565
FRUITS									
1	Jack *Fruit (Artocarpus integrifolia) (t/plant)*	0.047	4.525	0.049	9.15	0.052	7.67	0.056	4.28
2	Mango *(Mangifera indica)*	1.114	1.805	1.119	3.625	1.406	23.8	2.253	17.61
3	Pine *Apple (Ananas sativa)*	4.348	5.282	2.07	6.69	2.823	47.78	2.539	19.84
4	Orange *(Citrus sinensis) (in numbers)*	-	-	82.27	9050	67.3	4375	62.5	3000
5	Papaya*(Carica papaya) t/plant*	0.0137	1.345	0.0173	5.6	0.0163	6.2	0.0162	3.755

Note: P= Productivity (t ha^{-1} year^{-1}) ; TP= Total production (t)

3.1.5 Home-garden

The area around the house premises is grown with vegetables and cereals especially for domestic use. Maize is a major cereal for staple food grown in rainy season in uphill villages. The production of vegetables in commercial scale is mostly practised by foothill villagers and marketed in the nearby weekly market of Chatikona. Home garden provides variety of requirements to the tribal community round the year. Among vegetables, Tomato, Brinjal, Bin, Sweet Potato, Chilly are commonly practiced. The cultivation of Tobacco is taken up in small scales by the foothill villagers for chewing snuff and black cigar (pika, rolled Tabaco leaf). Apart from these, Papayas, Pumpkin, Bitter-Gourd are also cultivated. Tomato and Brinjal are major cash crops for the foothill villagers. The area used for home garden was recorded household-wise and presented village-wise in Table 2. These crops are mostly grown during rainy season. The area per village varies from 0.61 ha (Patlamba) to 15.2 ha (Papikhunti) across different villages.

3.1.6 Valley cultivation

Valley cultivation is taken up near the available natural water source i.e. Streams and Nalas flowing below the habitations. It is mostly the paddy crop practiced in one uphill village Rodanga and three foothill villages viz., Majhihalma, Bhaliabhatta and D.Kumbharbadi. The area of cultivation is estimated from individual households irrespective of own, revenue land or forest land. The plots of cultivation are very small and sizes are adjusted according to the area available on the Nala side. Sometimes, check dams and irrigation channels are constructed for the flow of water to the plots. In the uphill village of Rodanga, the household with good economical back ground cultivate paddy. In the three villages in foothill, all households go for cultivation in small plots. The per capita cultivation of paddy is highest in D.Kumbharbadi (0.130 ha.) and lowest in Rodanga (0.025 ha.). The total area of cultivation of paddy in the villages is much lower in Bhaliabata-3.46 ha compared to Rodanga with 7.22 ha., Majhihalma10.84 ha., and D.Kumbharbadi 13.07 ha. (Table 2). Paddy (*Oryza sativa* L.) cultivation is taken up nala beds and its adjoining areas for which primary productivity is calculated from the dry weight of the above ground components. The production of paddy (grain and straw) in Rodanga, Majhihalma, Bhaliabata and D.Kumbharbadi was 17.5 tons, 33.75 tons, 9.68 tons, and 41.75 respectively (Table 3,4). Annual productivity was highest in D.Kumbharbadi. The contribution of different components to totals above-ground productivity showed that the grain contributed 59.64% followed by straw 34.8 % and residue 5.56% (Table 5).

3.1.7 Cereals

Finger Millet (*Eleusine corocana* Gertn.) commonly known as Mandia is a staple food for the local community and produced in large quantities to meet the annual requirement. It is cultivated in Podu cultivation as a component along with other cereals like pearl Millet, common Millet , barnyard Millet s, legume and oil seeds. The total production i.e. grain and straw of different crops were considered separately as it is a mixed cropping pattern. The productivity of finger Millet varies from 2.061 t $ha^{-1}yr^{-1}$ to 2.744 t $ha^{-1}yr^{-1}$ in uphill villages (Tables 3-4) and from 1.552 t. $ha^{-1}yr^{-1}$ to 2.204 t $ha^{-1}yr^{-1}$ in foothill villages (Table 3-4). As regards the total production, the highest production is observed in village Khajuri. Disaggregation of the crop products are shown in Tables 5.

Common Millet (*Panicum paludosum*) is locally known as “Kangu” in Dongaria villages. Kangu is cultivated as mixed crop in the shifting cultivation area along with other cereal, pulses and oil seeds. The actual area it occupies in a mixed cropping pattern was taken by field measurement of individual area. The productivity was 2.737 t $ha^{-1}yr^{-1}$ in Patlamba, 1.411t in Rodanga, 0.549 t $ha^{-1}yr^{-1}$ in Khajuri and 0.864 t $ha^{-1}yr^{-1}$ in Gortali villages (Table 3). The Kangu is not practiced in foothill villages of Niyamgiri (Table 3-4). Pearl Millet (*Pennesetum typhoides*) is also cultivated in shifting cultivation area along with other cereals, pulses and oilseeds and locally known as “Ghantia”. It is also practiced in uphill villages of Niyamgiri with maximum productivity in Patlamba village 0.381 t $ha^{-1}yr^{-1}$ and minimum of 0.188 t $ha^{-1}yr^{-1}$ in Rodanga. Highest production was recorded in Gortali. Barnyard Millet **(***Echinochloa colonum*) is locally known as Koshala and cultivated as mixed crop in shifting cultivation area along with other Millet s, pulses and oilseeds in Rodanga (4.465 t $ha^{-1}yr^{-1}$) with minimum productivity in Patlamba (3.516 t $ha^{-1}yr^{-1}$). It is a major cereal of the uphill villages with highest production in Khajuri village and lowest in Patlamba.

Table 4. Agricultural crop productivity of the foothill village ecosystem

Crop		Majhihalma		Bhaliabhatta		D. Kumbharbadi		Papikhunti	
CEREALS		**P**	**T P**	**P**	**T P**	**P**	**T P**	**P**	**T P**
1	Paddy *(Oriza sativa)*	3.110	33.75	2.796	9.680	3.192	41.750	-	-
2	Maize *(Zea mays)*	0.193	1.550	0.190	0.870	0.184	0.880	0.192	0.650
3	Finger Millet *(Eleusine corocana) MANDIA*	2.204	19.900	1.888	7.800	1.706	13.400	1.552	11.380
4	Barnyard Millet *(Echinochloa colonum) KOSHALA*	-	-	-	-	-	-	3.709	27.180
LEGUMME									
1	Red Gram *(Cajanus cajan) KANDULA*	0.702	6.340	0.849	3.510	0.432	3.400	1.537	11.270
2	Jhudanga *(Vigna unguiculata)*	0.636	5.750	0.974	4.025	0.547	4.360	-	-
3	Katinga *(Vigna sps)*	-	-	-	-	-	-	-	-
OILSEED									
1	Castor *(Ricinus comunis) JADA*	-	-	-	-	-	-	-	-
2	Niger *(Guizotia obyssinica)*	0.071	0.646	0.078	0.325	0.055	0.435	0.356	2.615
3	Rasi *(Sesamum indicum)*	-	-	-	-	-	-	0.181	1.33
VEGETABLES									
1	Brinjal *(Solanumm elanogena)*	0.494	0.2	0.395	0.08	0.271	0.165	0.390	2.56
2	Tomato *(Lycopersicum esculentum)*	0.218	0.92	0.241	0.47	0.248	0.695	0.268	2.11
3	Lady Finger *(Hibiscus esculentus)*	0.300	1.035	0.382	0.48	0.260	0.97	0.277	0.225
4	Simba *(Dolichous lablab)*	-	1.054	-	0.54	-	0.675	-	1.58
CASH CROPS									
1	Cotton *(Gossypium hirsutum)*	-	-	-	-	-	-	0.799	5.76
2	Tobacco *(Nicotiana tobacum)*	-	0.04	-	0.01	-	0.06	-	0.02
3	Banana*(Musa paradisiaca)*	0.009	1.135	0.0086	0.65	0.011	1.75	0.0086	0.36
FRUITS									
1	Jack Fruit *(Artocarpus integrifolia) (t/plant)*	0.062	1.38	0.056	0.45	0.049	1.58	0.054	0.71
2	Papaya*(Carica papaya) t/plant*	0.0175	0.35	0.012	0.3	0.0138	0.9	0.0156	0.5

Note: P= Productivity (t ha-1 year-1) ; TP= Total production (t)

Table 5. Rate of fodder consumption (Mg) in villages of Niyamgiri hills

Item	*Villages*							
	P	**R**	**K**	**G**	**M**	**B**	**D**	**H**
Paddy Straw	-	6.093	-	-	11.75	3.37	14.53	-
Other Straw	34.556	84.796	105.738	91.204	16.93	7.946	10.864	30.728
Crop residue	9.317	24.062	32.026	27.31	7.586	3.969	6.485	9.833

Note: P- Patlamba, R- Rodang ,K- Khajuri,G- Gortali, M- Majhihalma, B- Bhaliabhatta, D- D. Kumbharbhadi, H- Papikhunti

3.1.8 Legumes and oil seeds

Red Gram (*Cajanus cajan*) is one of the most common pulses cultivated in all villages. The highest productivity was recorded in the village Papikhunti (1.537 t $ha^{-1}yr^{-1}$) whereas the lowest productivity was recorded in the village D. Kumbharabadi 0.432 t $ha^{-1}yr^{-1}$. Khajuri village recorded the highest production quantity of 20.538t followed by Gortali (17.568 t), Rodanga (13.464t) Papikhunti (11.270 t) Majhihalma (6.340 t) Patlamba(4.520 t) Bhaliabhatta(3.510 t) and D. Kumbharabadi (3.4 t). In green condition (immature fruits) it is used as vegetables but mature production is good saleable pulses. Jhudanga (*Vigna unguiculata*) legume is used as vegetable in green stage and as pulses in mature harvest. Seven villages produce Jhudanga except Papikhunti. Highest production recorded for Gortali (19.190 t) whereas Patlamba produced the minimum quantity of 1.475t. Gortali showed the highest productivity of 1.350 t $ha^{-1}yr^{-1}$. Kating pulses are produced by the four uphill villages. It is commonly cultivated as mixed crop and used as pulses. Maximum production of 8.551t was recorded in Khajuri village though highest productivity was recorded in Gortali (0.447 t $ha^{-1}yr^{-1}$). The production is entirely consumed by villagers. Among Oil Seeds**,** Castor (*Ricinus communis*) is sown in rows on sides of shifting cultivation area and seeds collected when mature. It is practiced in uphill villages only. The productivity is only indicative of individual production subjected to density of crop. Niger (*Guizotia obyssinica*) is cultivated in small plots and used as oil seeds. The productivity was highest in Papikhunti 0.356 t $ha^{-1}yr^{-1}$ with highest production of 2.615 t. Rasi (*Sesamum indicum*) is cultivated only in one foothill village Papikhunti.

3.1.9 Vegetables (Home Garden), cash crops and fruits

Common vegetables cultivated are Brinjal, Tomato, Lady Finger and Simba. The product is only meant for domestic use in uphill villages whereas commercial cultivation is recorded from foothill villages. Papikhunti is the highest producer of vegetables which is marketed in weekly market of Chatikona home garden. Turmeric (Curcuma Longa) and ginger (*Zingiber officinale*) are major cash crops of the uphill villages cultivated in mid hill areas. The maximum production has been recorded from Rodanga for turmeric (10.33 t) with highest productivity 0.893 t $ha^{-1}yr^{-1}$ (Tables 3-4) Patlamba has minimum production 0.548 t and lowest productivity 0.564 t $ha^{-1}yr^{-1}$ for turmeric. Cotton (*Gossypium hirsutum*) and Tobacco (*Nicotiana tabacum*) are not cultivated in uphill villages but noticed in few foothill villages. It is in small quantity for self-use not sold outside. Jack Fruit (*Artocarpus integrifolia*) (green) is collected and sold as vegetables in late winter. Truckloads of jack fruits exported to distant places of Odisha and Chhattisgarh. It is centre for green jack fruit in Odisha and market value is better than matured ripen ones. Green jack fruit is produced in all villages both uphill and downhill villages. Maximum production is recorded in Rodanga (9.15 t). Almost all crop is sold in green condition which has great demand. Mango cultivated variety has been raised in different villages with assistance of DKDA. The laborious family has developed good orchards in mid hill areas and growing pineapple as under crop. The productivity varies from 1.114 (Patlamba) to 2.253 t ha-1yr-1 (Gortali) and it is mostly sold out. Pineapple (*Ananas sativa*) is generally grown as under crop in Mango orchards and sometimes pure crop raised in slope of mid hill. Highest quantity was produced in Khajuri village (47.78 t) and lowest production recorded from Patlamba (5.282 t). This is marketed in weekly markets, Railway Platforms and delivered to traders at village site. It is not produced in foothill villages. Orange (*Citrus sinensis*) cultivated varieties promoted by DKDA has been successful in some villages of uphill areas. It has also good local market for quality of fruit. Railway communication helps in marketing of different products. Highest production was recorded for village Rodanga (9050 numbers). Papaya

(*Carica papaya*) Plants are grown in home garden area and highest production was recorded from village Rodanga (5.6t) which is sold outside.

The grains were separated from straw and residues for cereals, pulses and oilseeds. The grains are kept for human consumption whereas the straw and residue are either left to nature to decay or partly utilized by domestic animals. Among all the crops, straw production was maximum for the Paddy (843-1110 Kg $ha^{-1)}$, Finger (925-1290 Kg ha^{-1}) and Barnyard millets (2431-2962 Kg ha^{-1}) and residue production followed the same pattern for Paddy (133-176 Kg $ha^{-1)}$, Finger (263-492 Kg ha^{-1}) and Barnyard millets (525-629 Kg ha^{-1}) across villages. Red gram crops also contributed significantly in enriching the fields with straw and residue to help increasing the fertility value of croplands. Other crops like Maize, Niger and castor had no contribution in production of straw in the fields, however small quantity of straw/residue of Niger crop in villages of Rodanga, Khajuri, Majhihalma, Bhaliabhatta and Papikhunti were estimated for crop fields. The total production of biomass is divided into grain, straw and residue basing on the sampling result of each village. This provides data on total grain production of the village which will be consumed or sold outside. Similarly, the straw and residue which are properly utilized by the foothill villagers as domestic animal feed is left unused by the uphill villagers mostly allowing natural decay. The disaggregation of different components such as grain straw and residue are shown in Figs. 9-13 as percentage contribution of the component to the productivity.

4. DISCUSSION

Niyamgiri hills in Rayagada district have attracted many researches for the study of cultural and socio-economic life of Dongaria Kandha “Particularly Vulnerable Tribal Groups” (PVTG). The villages are surrounded by hilly forests of high altitudes and create micro-climatic effect in the locality. The economy is dependent on agriculture practice, MFP collections and to some extent animal husbandry. All the major activities of the village ecosystem were found to be linked to forest ecosystem directly or indirectly and are related to their socio economic and cultural traditions. The village ecosystem is a complex comprehensive system composed of human society and the natural environment. This system is constantly developing and changing in the process of operation [19]. In our study, Patlamba village has the lowest family size of 3.8 which is greater than the family size of 3.6 of tribal villages of Ganjam district of Odisha [4]. The highest value of family size 5.1 in village Khajuri is more than that of coastal villages (4.7) of state as reported by Sahoo and Mishra [20].The average per capita cultivated area (0.117 ha) Patlamba was lower than the value (0.18 ha) reported for the Bhogibunda tribal village ecosystem [4] and the average value (0.26 ha) for India [21].

The four uphill villages focus on the Podu cultivation to produce minor Millets like finger Millet , common Millet , pearl Millet and barnyard Millet with pulses like Red gram and Jhudanga (*Vigna* sp). The Mid Hill orchard provides fruits of Orange, Pineapple, Jackfruit and Mango for sale with cash crops of Turmeric and Ginger. Podu cultivation was traditional practice known as shifting cultivation as the tribal people used to shift to a new place periodically and then return. This land use pattern enhances soil erosion as the seeds and all growths cut and burnt before seeding. It is not an eco-friendly practice and gradually reduces forest cover but Podu activities are taken up manually and no tilling is done by draught animal prohibiting Carbon loss. Further, Podu cultivation of red gram (kandula) increases soil fertility by fixing atmospheric nitrogen but reduces the area and quality of forest. Fertilizers, pesticide, irrigation or organic manure are not applied in Podu cultivation. Once some alternative is provided, Podu areas can be used for artificial regeneration of tree crops [22-24]. Leaving crop residue in the field allows build-up of organic matter, thus, help building beneficial flora and fauna in soil. Organic farming is expanding rapidly and the process of transitioning from modern to organic agriculture may help to control pests biologically, manage nutrient cycles, produce different crops and tap new markets. However, in these villages, the Crop yields may not reach to a level to generate profits. Today also, the tribals are unable to get organic premiums while selling in local market due to lack of organic certification and market support. Hanson et al. [25] suggested that subsidized crop insurance may be considered for farmers as the organic products market is increasing rapidly and some markets may be sensitive to oversupply and prices may be highly variable.

The production of minor Millet is prominent in uphill villages and productivity is higher than the district average productivity of 656 kg ha^{-1} [26].

The cause of higher productivity may be attributed to better soil fertility and cultural operations. Among the foothill villages, Millet productivity ranged between 559 -794 kg ha^{-1}) which is at par with Rayagada district . Lower productivity in some foot hill villages maybe due to eroded soil cover with lower fertility. Barnyard Millet productivity ranges from 633 kg ha^{-1}(Patlamba) to 803.71 kg ha^{-1} (Rodanga). Well drained fertile soil with the effect of slash burning process before sowing of seed provides good growth and more productivity. Though records of comparison are not available, it can be considered in the line with finger Millet .Pearl Millet is the mixed cropping system and productivity varies from 56.4 kg ha^{-1} to 110.5 kg ha^{-1}. common Millet locally known as "Kangu" is added to the Podu cultivation mixed cropping where productivity value ranging from 87.82 kg ha^{-1} to 424.45 kg ha^{-1}. The maize productivity in these villages ranged between 184 and 340 kg ha^{-1} across all villages except Papikhunti village with 1173.28 kg ha^{-1}, which is comparable to the District record of Rayagada 1112 kg ha^{-1} in 2010-11 [26].

India is the largest producer of Millets in the world and two varieties of Millets viz., Pearl Millet (Bajra) and Sorghum (Jowar) together contributed approx. 19 per cent of world production in 2020. Finger Millet is the richest source of calcium (300- 370 mg/100 g). India's Pearl Millet production accounts for 40.51 per cent followed by Sorghum 8.09 per cent in the world production of Millets in 2020. India's average yield in Millet farming (2021-22) is 1208 kgs per hectare. In 2021, approximately 12.3 kgs of Millet was available per person. In 2021-22, Pearl Millet contributed 58% to the total Millet production, followed by Sorghum (29%) and Finger Millet (10%). Millet production in India is expected to continue to grow in the coming years [27]. The villages of this study area have far lower productivity compared to productivity of finger Millet in other agriculture village ecosystem like Ungra (1.23 t ha^{-1})as reported by Rabindranath et al [2] and Bhabinarayanpur (1.08 t ha^{-1}) by Nisanka and Mishra [3]. Data on Jowar Millet production data in India revealed a production figure of 619-634 kg per ha in Odisha, 2689 in Andhra Pradesh and 1935 in Madhya Pradesh with all India average value of 1025 during 2017-2021. The consumption of Millets can effectively solve the problem of anaemia from the world [28]. The Red gram productivity ranged from 432- 1537 kg ha^{-1} with lowest in Bhaliabhatta and highest in Papikhunti. The productivity in general is higher in uphill villages for their soil condition and intensive traditional care. Among foot hill villages, Papikhunti villagers concentrate on Podu cultivation as their land is suitable with good soil depth and soil fertility. The productivity of Jhudanga varies from 269 kg ha^{-1} (Patlamba) to 1350 kg ha^{-1} in Gortali and of Kating varies from 331 kg ha^{-1} (Rodanga) to 447 kg ha^{-1} in Gortali. It is not cultivated in foothill villages. Foot hill villages sell the surplus vegetables in the local market. Papikhunti village recorded highest area under home-garden cultivation being nearer to market area for comfortable marketing avenue. The productivity of paddy was 2.424 t ha^{-1} yr^{-1} which is far lower than the productivity at lower elevation of Meghalaya 3.71 t $ha^{-1}yr^{-1}$ [29]. The Paddy productivity in three villages (except village Papikhunti) ranged between 2.796 t $ha^{-1}yr^{-1}$ and 3.192 t $ha^{-1}yr^{-1}$ which is less than the plain lands of Odisha [3]. The lower productivity in both uphill and foothill villages can be attributed to the subsistence farming system followed by the tribal people without modern inputs. They depend on natural fertility of soil without adding any organic or in-organic manure. The seed input is also age-old local variety and the cultural operations are not followed properly.

4.1 Impact of Straw and Residue Harvest

Figs. 9-13 give an idea of how these villages are able to continue with this primitive agriculture system for so many years with subsistence productivity to meet their livelihood needs. Of all the Millet production in Patlamba village, grain constitutes 16-34%, the straw and the residue constitute respectively,48-67 and 12-19%, while grain constitutes 16-35%, the straw and the residue constitute respectively,49-68 and 10-20% in Rodanga village, grain constitutes 16-35%, the straw and the residue constitute respectively,48-65 and 14-19% in Khajuri village and grain constitutes 16-35%, straw and the residue respectively,47-68 and 14-19% in Gortali village of the total output. Therefore, almost one third of the Carbon and nutrients returned to soil in these cultivated areas of the villages. The residue harvest removes more nutrients from the agroecosystem than grain harvest alone.

Holt [30] predicted greatest loss from both residue removal and losses resulting from expected erosion increases with reduced soil cover. Lindstrom [31] reported net losses of nutrients for high removal rates in no-till corn,

suggesting that increased fertilization rates will be needed to maintain soil fertility. Increased crop yields was reported by Power et al. [32] when residues were left on the soil surface compared with yields under residue removal. In the driest years, they observed that yield increases to residue-induced water conservation and recorded benefits from reduced erosion and increased soil organic matter Clapp et al. [33] and Linden et al. [34] found that production in residue-returned treatments exceeded those with no residue by approximately 22% in drier than average years. They also observed relationships between reduce tillage (chisel plow) and no-till cultivation. The study villages have been able to continue with agriculture activities mainly due to their traditional practice of leaving the residue in the field. That promotes regeneration of nutrients and moisture and also reduce soil erosion. Straw constitute 47-68% of the total production which is acting as mulching and nutrient amendment material in the field. Similarly, the residue with 12-20% also increases the soil health to facilitates next crop productivity.

Sauer et al. [35] found that residue age and placement affect soil moisture and temperature and fresh residue, being thicker, provided more insulation and, therefore, reduced evaporation and Soil temperature due to surface reflectance than weathered residue and bare soil content [36]. It is well concluded that residue removal results in increased erosion, reduced SOM and nutrient levels, and lower biotic activity that affect yield. The current practice of villagers also is a form of potential economic trade-offs that residue removal may require input higher fertilizer costs, reduced soil quality and soil organic matter (SOM).

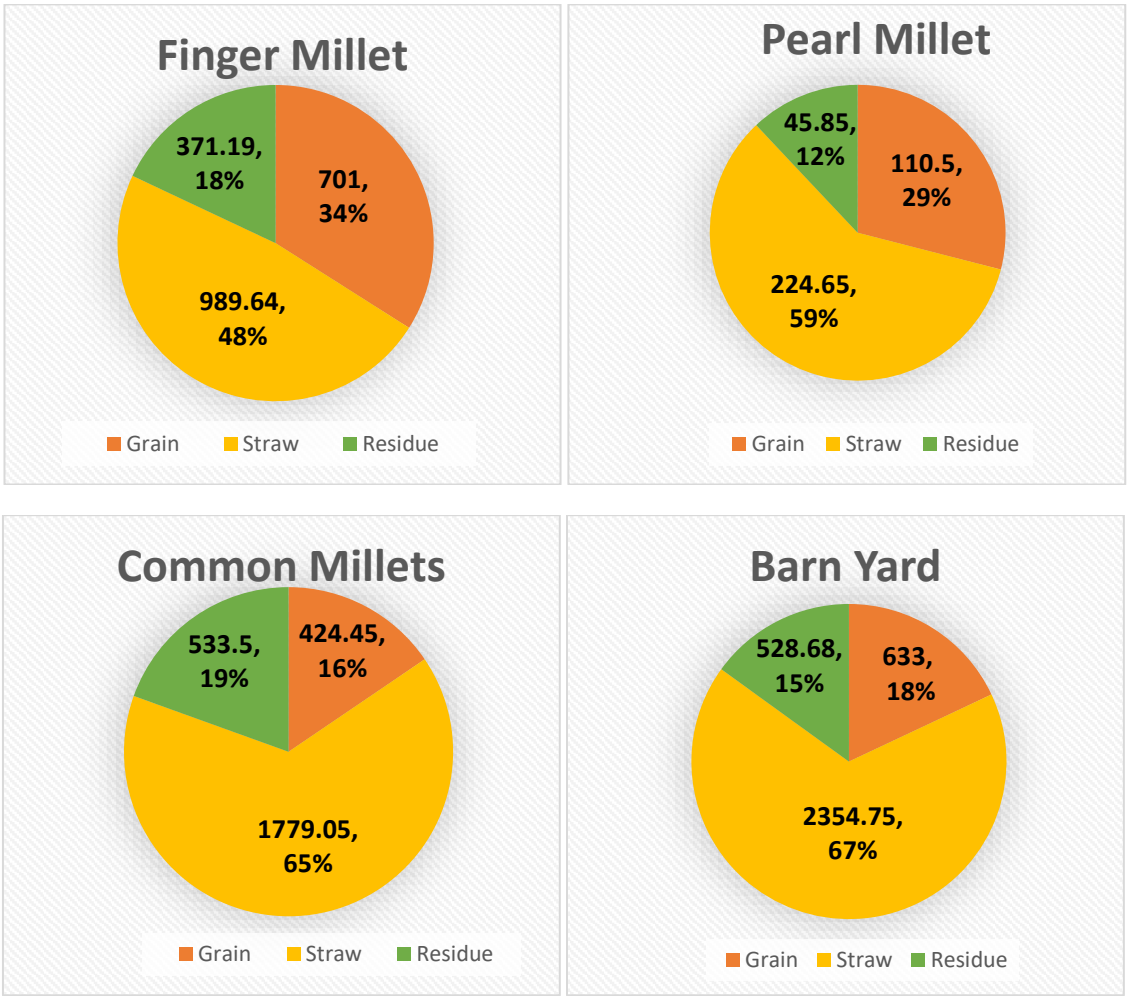

Fig. 9. Contribution of grain, straw and residue production (Kg ha$^{-1)}$ and (%) in village Patlamba

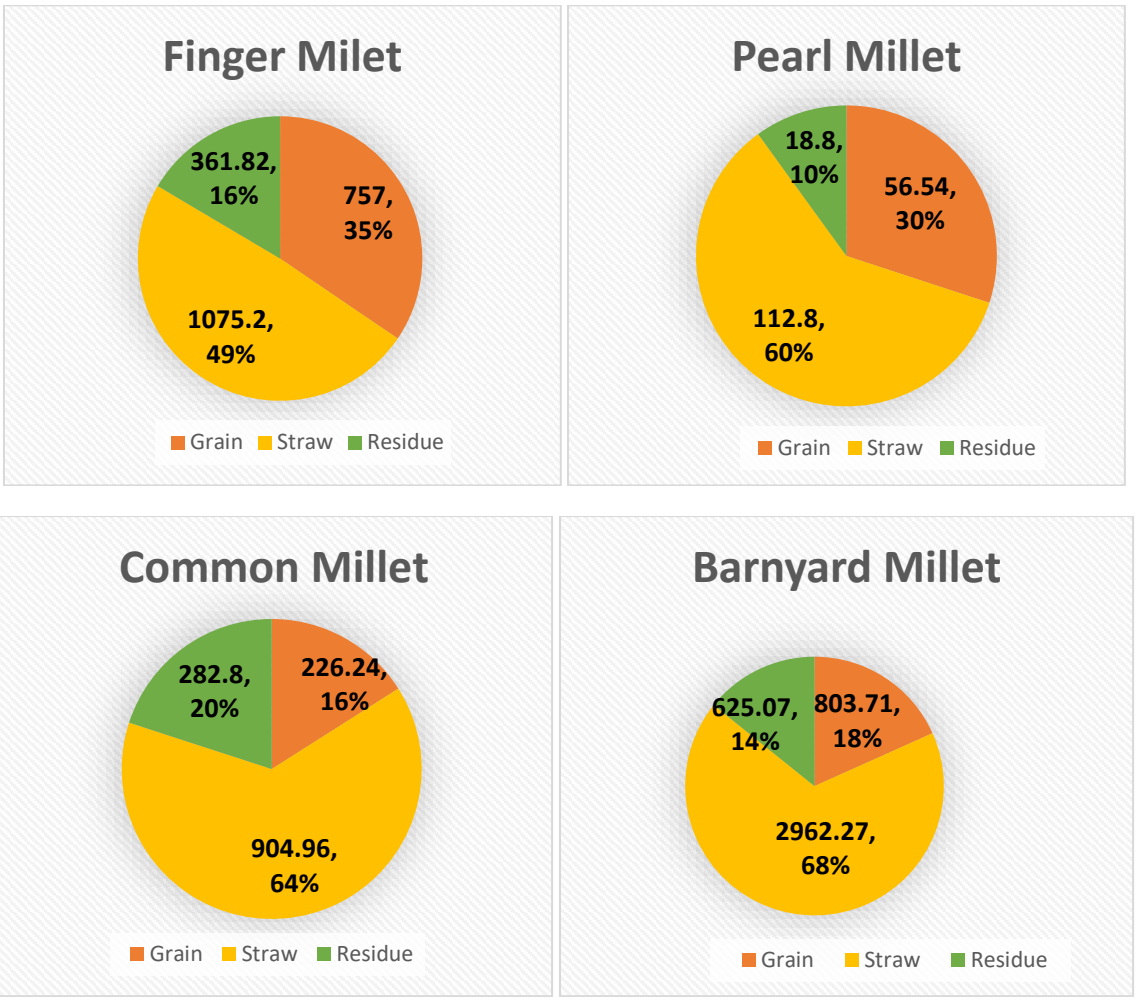

Fig. 10. Grain, Straw and residue production (Kg ha^{-1}) and proportionate contributions (%) in village Rodanga

4.2 Fodder Consumption

The uphill villagers entirely depend on forest for feeding the animals of all category. The villagers provide shelter only to the cattle if available. But four villages at the foothill provide stall feeding besides grazing the animal in forest. Straw and other crop residue, husk and bran of grains are used as fodder and feed. Paddy straw, finger Millet straw, etc., bran and husk of grains, raw vegetable waste are given to animals as stall feed and fodder in foothill villages.

Paddy straw consumption was 6.093 t in Rodanga, 16.88 t in Majhihalma, 14.537t in D. Kumbharbadi and 11.873 t in Bhaliabhatta (Table 5). Grasses and other green twigs have not been taken into account as stall feeding of grass was seldom practiced. Of all the Paddy production, while grain constitutes 60%, the straw and the residue constitute respectively,35% and 5 % of the total output in four villages.

The trend of expanding crop biodiversity worldwide is now being reversed. The shift in agricultural production towards monoculture, and cash crop and distribution systems towards greater commercialization, increased technological inputs and globalization is associated with the rapid decline in crop biodiversity especially in tropical world which houses most of the biodiversity banks and germplasms. The magnitude of the loss is substantial i.e., thousands of rice varieties disappeared from Indonesia rapidly when the planting of local varieties was banned [37]. It is reported that over 10,000 varieties of wheat were grown in 1949 In China and that reduced by 90% by the 1970s [38]. This has happened in case of other major crops and fruit and vegetables all over the world.

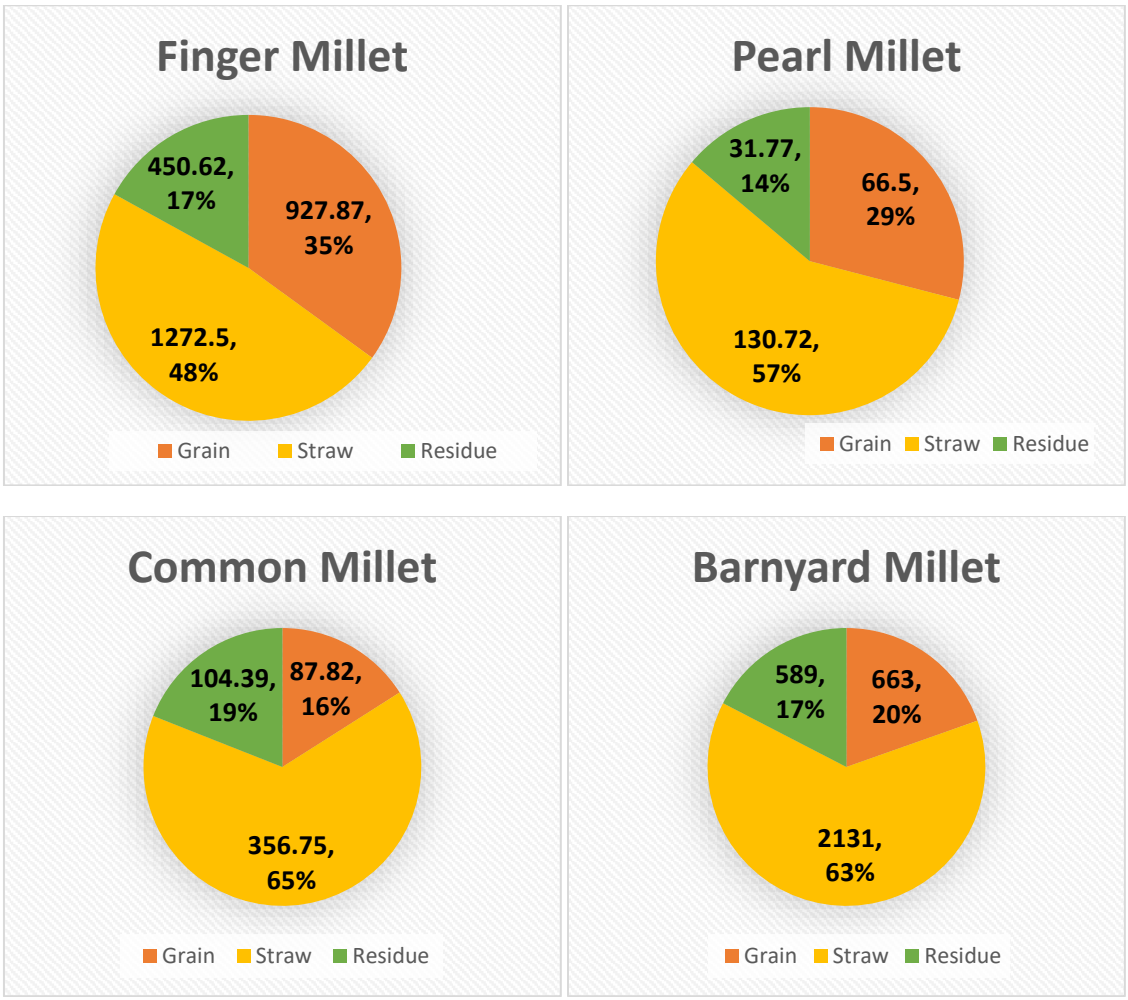

Fig. 11. Grain, Straw and residue production (Kg ha$^{-1)}$ and proportionate contributions (%) in village Khajuri

The material flows were more or less similar among the villages of the Niyamgiri hills, however, crop productivity differed considerably due to perhaps quantities of materials flowed, and more input in case of some crops in valley villages than uphill villages. The details of food consumed in these villages indicated that the local production supported only less than 50 % of requirements and rest is met through imports. The increased preference to marketable crops and easy accessibility of food grains imported from plains are the results of market forces. But the reliance on local produce (traditional grains) is relatively high in these villages very similar to Himalayan villages [39].

The Agro-ecosystem studies in central Himalaya indicated that agricultural in the area can be sustainable if pressure on forestland can be reduced. This could be achieved by reviving the support system and each hectare of agriculture land should be supported by 10-15 ha of forests [40]. Carrying capacity of forests at present seems to be capable of supporting the village agriculture. However, all effort is needed to strengthen the protection mechanism in forest blocks surrounding the villages, and involving the people of these villages in other forest-based livelihood option other than agriculture. Similar recommendations for villages located inside the Similipal forests has also been given as a result of one study on human ecology of villages [41]. Intensification of food crop production systems in villages may lead to further loss of many ecosystem functions affecting especially sustainable productivity and nutrient cycling which will ultimately result in continued degradation of Carbon sequestration and biodiversity [42-46].

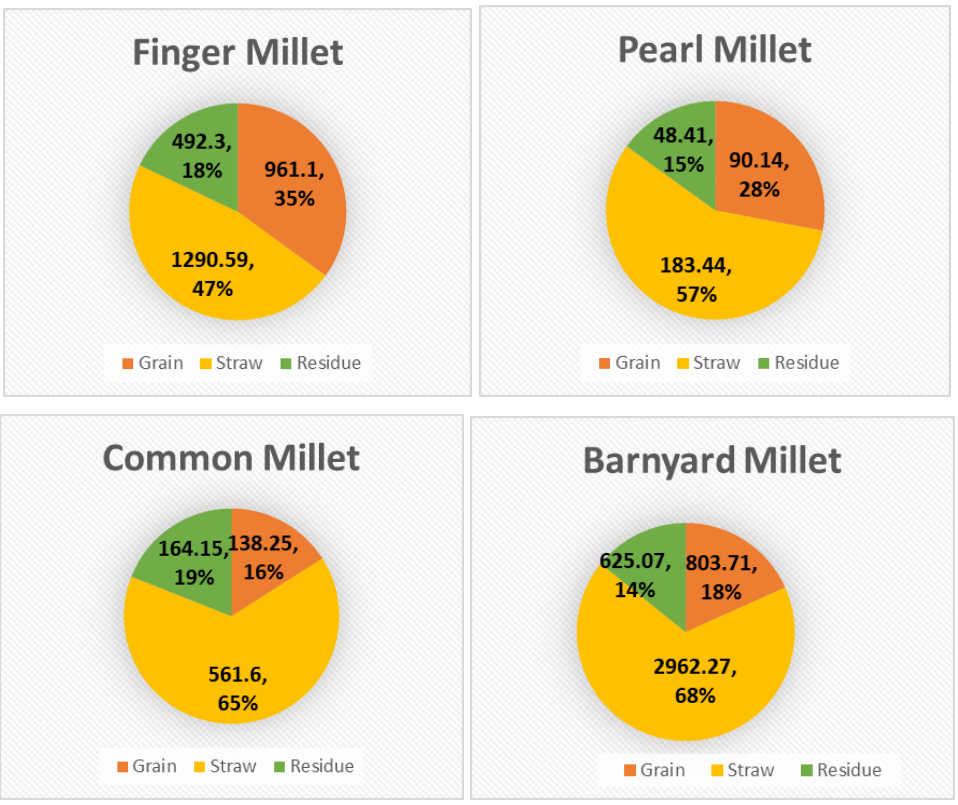

Fig. 12. Grain, Straw and residue production (Kg ha^{-1}) and proportionate contributions (%) in village Gortali

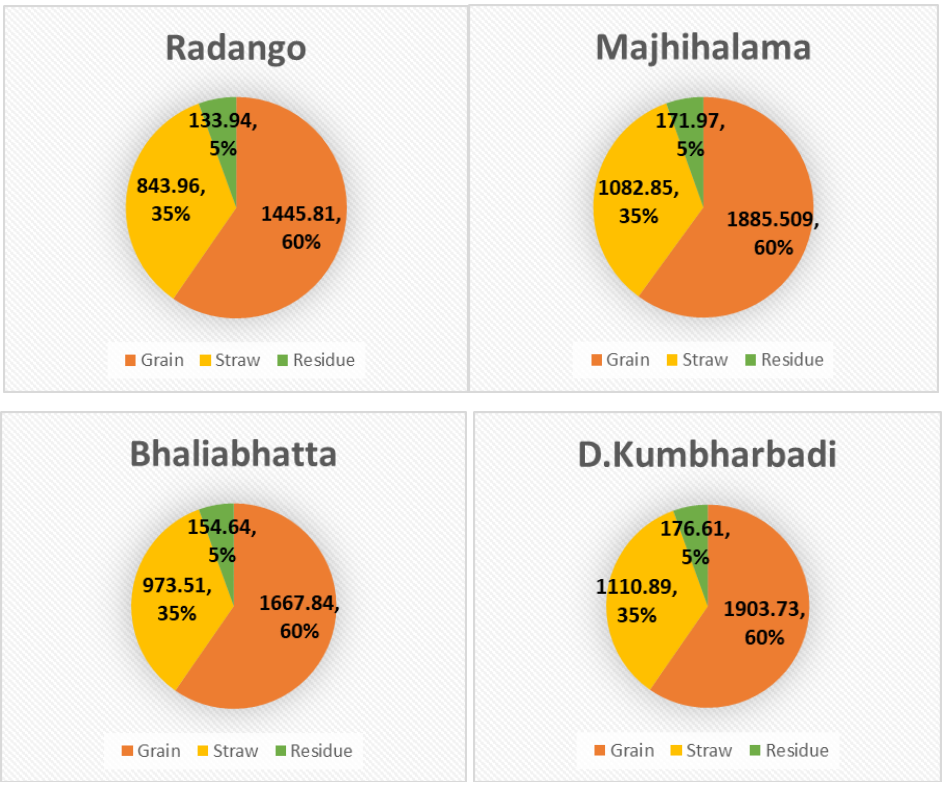

Fig. 13. Contribution of Grain, Straw and residue production (Kg ha^{-1}) in Harvested Paddy in villages

5. CONCLUSION

The present study village ecosystems in Niyamgiri Hills are inter-related with the forest ecosystem. The material deficit of the village ecosystem is met either by meeting the needs from nearby forests or by procuring materials from outside these systems. The production of agriculture sub-system is not sufficient to meet the food requirement of villages and Government supported PDS rice meet this gap. However, crops like horticulture and a few Millet crops grown in the uphill villages are exported to markets as these are high energy valued products. Odisha Millet Mission (OMM) may need to provide interventions to these villages with modern approach to increase Millet productivity as Mission aims to revive Millets on farms and plates with simultaneous focus on Production, Processing, Consumption, Marketing, and inclusion of Millets in Government schemes [47]. The program is to address the issues of food and nutrition security through the promotion of native Millets. These villages qualify to be included in the overall objectives of OMM increasing productivity of Millet crops through improved agronomic practices, increasing household consumption, setting up of processing units near villages, conservation and promotion of local varieties of crops and land races and better marketing of Millets through farmer producer organizations.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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