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Linkages between Agriculture and Forest: Case Study from three tribal villages located in a Biosphere Reserve of India

Liens entre Agriculture et Forêt : cas d'étude de trois villages tribaux situés dans une réserve naturelle en Inde.

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Résumé: La présente étude est consacrée à un écosystème agro-alimentaire développé dans trois villages situés au sein de la réserve naturelle de Similipal, dans la région d'Odisha, en Inde, entre 21°30' et 22°08' de latitude nord et entre 86°05' et 86°37' de longitude est. L'agriculture est le seul gagne-pain des populations de ces trois villages, Jenabil, Nawana et Ghodabindha localisés respectivement au cœur de la réserve, dans une zone tampon et en périphérie. C'est à Jenabil, au cœur de l'écosystème que l'agriculture est la plus performante alors que le prélèvement d'énergie en forêt est moindre par rapport aux deux autres localités. Il ressort que l'environnement est mieux capable de supporter une agriculture naturelle intégrée au cœur de l'écosystème. Il est donc fortement recommandé d'activer un mécanisme de protection du milieu naturel dans les zones tampon et en périphérie.

Mots-clés: Inde, Odisha, Similipal Biospere Reserve, Villages, Agro-Ecosystème, Energétique

Abstract: The present study was conducted in the Similipal Biosphere Reserve, Odisha, India. Three tribal villages located inside the biosphere reserve at different altitudes were selected for the agro ecosystem study. The biosphere reserve located at 21^0 30' to 22^0 08'N latitudes and 86^0 05' to 86^0 37'E longitudes, presents a typical example of Mahanadian bio-geographic zone. The agriculture is the main source of livelihood in these three villages. The forests across these ones vary from 25.30 to 231.59 ha, and agriculture area from 74.61 to 155 ha. The area not suitable for cultivation is highest in peripheral village Ghodabindha, and lowest in core village Jenabil. The total village area is greater in buffer village Nawana and smaller in core village Jenabil. Jenabil is highly dependent on agriculture and carrying capacity is high enough to support existing human population. For Jenabil village 73 % of energy derives from forests, whereas forests contribute to 84% of the total energy consumption in Ghodabindha village and of 92% in Nawana village. There is no much difference in pattern of energy consumption of core and buffer villages as both depend on agriculture. Agriculture in core village is much more energy efficient than buffer and periphery. Total annual consumption was much higher in periphery and buffer due to easy access to market and high population requirements. Carrying capacity of Similipal forests at present seems to be able of supporting the core village agriculture. We recommend strengthening the protection mechanism in forest blocks surrounding the buffer and peripheral villages.

Key words**:** India, Odisha, Similipal Biosphere Reserve, Villages, Agro-ecosystem, Energetics

INTRODUCTION

Biodiversity loss from ecosystems imposes real costs on resource users (HEYWOOD, 1995). Reduction in species diversity due to intensification may affect the functioning of agro-ecosystems and can cause changes in environmental conditions (PERRINGS et *al.*, 1995; CONWAY, 1993). The habitat loss is associated with the processes of deforestation and desertification and consequent loss of biodiversity in areas where a high proportion of output and/or employment derives from agriculture (BLITZER et *al*.2012). Biodiversity loss due to agricultural growth may be associated

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with both, regions of low population density but high population growth (Sub-Saharan Africa and Latin America) as well as regions with high rural population density and growth (South Asia and South East Asia). The pressure in Asian regions has been increasing on remaining forest areas with higher rates of deforestation than in other regions. The conversion of remaining forests is at the rate of more than 2 per cent a year during 1980s in some Latin American countries while Bangladesh, Pakistan, Thailand and the Philippines were all converting remaining forest resources at 2.9 to 3.0 per cent a year (WRI 1994). The driving force behind the degradation of agro-ecosystems was poverty-induced pressure on forests in order to meet basic needs (WCED 1987). The tropical forests and the forest-derived agro ecosystems provide diverse services to local communities which include food, fuel, timber etc..., besides regulating locally-important environmental services, like water, carbon sequestration, air quality, nutrient supply, and regulation of pests and diseases.The village's population in the developing world mainly derive their livelihood from agriculture activities (FRESCO, 1984) including food production to meet the needs of increasing population (SNEEP *et al*. 1979). As population outgrew food production in many countries, the natural forest areas were used to expand the cultivated area. The land use changes by converting natural habitats especially for agriculture and other developmental purposes are major drivers of environmental changes affecting natural ecosystems. Exchange of energy from one habitat to the other can influence ecosystem functions (FAHRIG, 2003; EWERS & DIDHAM, 2008**).**

Similipal forest ecosystem in India enjoys status of Biosphere Reserve and is covered under the provisions of Wildlife (Protection Act, 1972) of the Country as National Park. The villages located inside Similipal Biosphere Reserve obtain food, fiber, timber, fuel wood, feed for livestock, and a host of other major products from forests and practice different forest-derived land use systems. Whether the village practices are impacting certain ecosystem services like biodiversity while deriving food, fiber, and feed... for local livelihoods at the expense of some ecosystem services, need to be scientifically examined. The modified ecosystems providing food, including fruits and products as cash commodity crops for economic gains to the village communities can co-exists with the natural forest and must ensure sustainable level of biodiversity to maintain hydrological and other ecological supporting functions. The present paper examines the impact of modified (agriculture) ecosystem in three tribal villages on the structural characteristics of the Biosphere reserve and tribal population. Our study aims at finding out whether present system at current level of agro ecosystem practices are sustainable in terms of ensuring long term provisioning and regulating services of forests including biodiversity.

STUDY SITES AND CLIMATE

Similipal was declared Orissa's 1st and country's 8th biosphere reserve on June 22 1994 under UNESCO's Man and Biosphere programme. The forests of Similipal are highly biodiverse providing a good habitat for wild animals and various indigenous tribal populations. The history of Similipal is a long story of the destruction of forests when British started influencing the management of Similipal forests for business interests. The long-term leases were granted to timber companies for providing slippers for laying railway lines. The timber contractors brought Tribals form Ranchi, Singhbhum, Midnapore and other places of Jharkhand and West Bengal to work in forest operations. Due to favorable conditions for agriculture in Similipal forests, a few tribal groups settled there. With series of depopulation and reoccupation of tenants in Similipal, there still exist 4 villages in core zone, 65 villages in buffer zone and about 1100 villages in peripheral zone.

The Similipal biosphere reserve is located between 21^0 30' to 22^0 08' North latitudes and 86^0 05' to 86^0 37' East longitude. The reserve has a total area of about 4,374 Sq Km of which 845 Sq Km is designated as core zone of Similipal Tiger Reserve (STR) and 2,129 Sq Km is buffer zone (1905 Sq Km of STR buffer + 77 Sq Km of Nato reserve forest + 147 Sq Km of Satkoshia reserve forest) and remaining about 1400 Sq Km in transitional zone or peripheral zone.

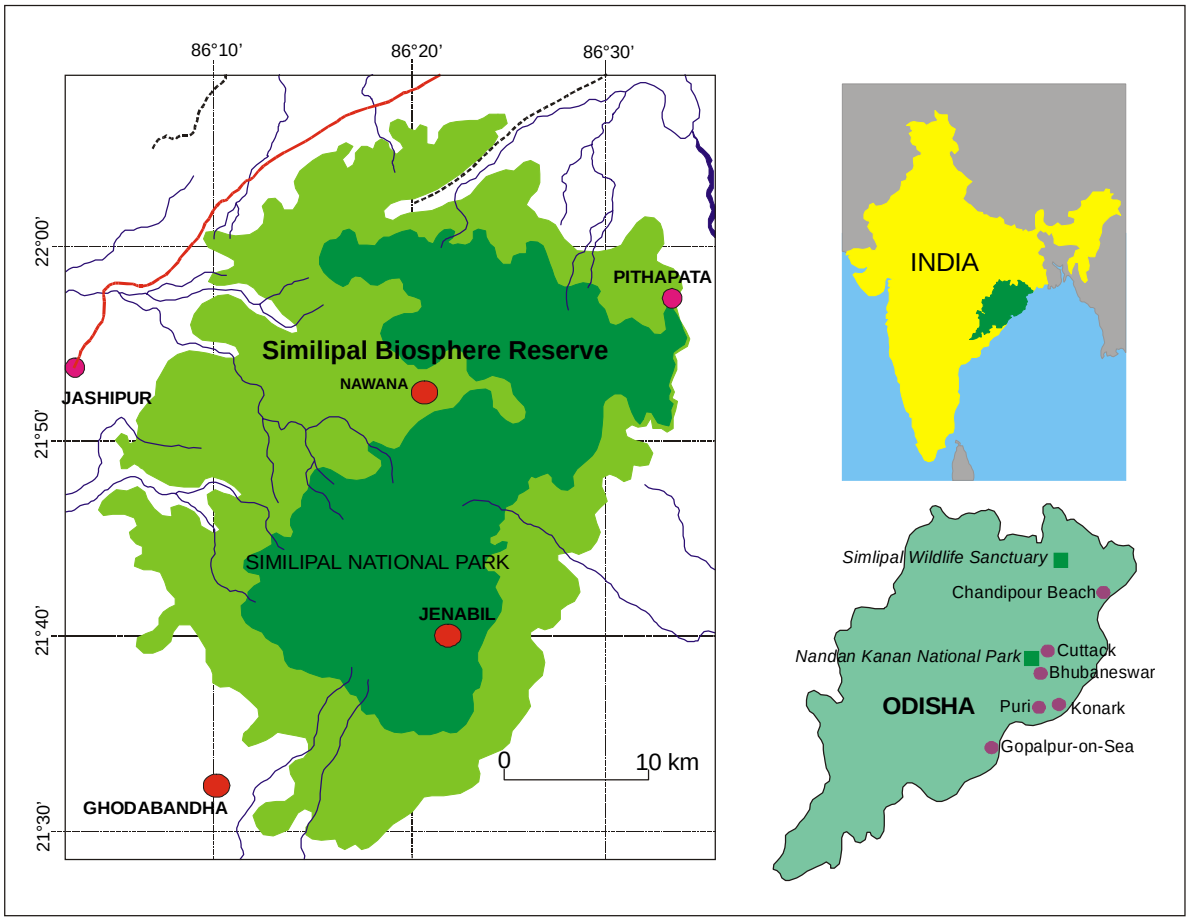

Fig. 1 : Smilipal Biosphere Reserve and location of study sites (Drawn from internet source)

The soil of all the forest sites is reddish in colour and loam to sandy loam in texture. The soil is slightly acidic in nature with pH ranging from 5.23 to 6.52 and average monthly soil moisture content varies from 18.13 to 40.25 %. The climate of the area is monsoonal and divisible into three seasons; summer (March-June), rainy (July- October) and winter (November-February). The climatic description is based on temperature and rainfall. The average annual rainfall varies from 28.11 to 395.96 mm, and is largely restricted to the period from July to October. Pre-monsoon showers are received during May and June. Post monsoon showers are received during November and December.The mean maximum temperature varies from 16.39^{0}C (December) to 35.03^{0}C (June) and mean minimum temperature from 5.7^0 C (January) to 21.57^0 C (June). The natural vegetation is moist deciduous type (CHAMPION AND SETH, 1968) and is dominated by *Shorea robusta*, *Anogeissus latifolia*, *Buchnania lanzan*, *Dillenia pentagyna*, *Syzygium cumini* and *Terminalia alata*, etc. (MISHRA et *al* 2006)

METHODOLOGY

Several revenue villages are located inside the Similipal biosphere reserve. Most of these villages are established in the valley areas. In core zone there are four revenue villages and in buffer zone there are 61. However in peripheral zone there are about 1200 villages. A through survey was done to get the representative village and a total of three sample villages were selected to collect ecological data on human-forest interface for agro ecosystem study. The village Jenabil was selected from the core zone, about 65 Km from Jasipur town and located at an elevation of about 870 meters under Gudgudia grampanchayat. Second village Nawana located in buffer zone is about 55 Km from Jasipur at an elevation of about 730 meters under Astakumar grampanchayat (village

community organisation). Third village Ghodabindha is located in the peripheral zone, about 10 Km from Thakurmunda at 360 meters elevation under Hathigora grampanchayat. (Figure1). A household survey was conducted on a well-structured questionnaire between July 2003 and June 2004. Each Household was studied and the data on live stock, house type, house structure, infrastructural amenities, agricultural land, seeds, fertilizer, pesticides, cow dung, human and animal labour and fence wood applied as agricultural input and crop output, kerosene, fuel wood and food consumption in the house hold and social traditions were collected. The census data of 2001 was used for calculation of demographic parameters. All agricultural and village data were converted to energy values using constants (CHANDOLA, 1976: MITCHELL, 1976: GOPALAN et *al* 1982).

RESULTS AND DISCUSSION

Demography and Living conditions

Demographic figures such as number of households, total population, children's population, workers and non-workers and number of schedule tribe population in these villages are presented in Table1-3. The percentage of "Tribals" to total human population in these villages is more than 96%. The total population, total number of Households and literacy rate are much lower in village Jenabil than other villages. The sex ratio is highest in Ghodabindha followed by Jenabil and Nawana (Table-1). Differences in living conditions vary among the study villages due to differences in proximity to road and urban centers like markets etc. The core and buffer villages are not having any pucca (brick & mortar) houses. The pucca houses are only seen in Ghodabindha (20% of the total houses) with a roof of cement or asbestos tiles, walls of stone or brick and wooden or iron door and windows (Table-2). The semi pucca houses (clay and brick) are common in all these three villages (more than 33% of total houses). The semi pucca houses have the Khappral tiled (baked earth tilles) roof brick and mud walls. Wood is also used extensively in walls and roof. The doors and windows are wooden or made of bamboo. Number of houses in all these villages is made up of Paddy or grass thatched roofs; walls are made up of mud or wattle leaf and twigs, doors are of cane and bamboo (Kachha houses). Kachha houses made up of only mud and earth materials are far larger in number (almost 60%) with core village exhibiting high percentage.

Table.1 Demographic details of study villages amenities & land use of villages

Demographic figures	**Jenabil**	**Nawana**	**Ghodabindha**
No of households	27	58	92
Total Population	145	305	471
Male	74	165	223
Female	71	140	248
Sex-ratio	1042	1179	899
Children's (below 14 yr age)	34	66	110
Total worker	87	166	184
Non-workers	58	139	287
Schedule tribe (ST)	145	292	462
% ST	100	95.74	98.09
Literates in number	13	57	90
Illiterates in number	132	248	381

Table 2. Details of various kinds of amenities in study Villages

Items/ Amenities	Jenabil	Nawana	Ghodabindha	Mayurbhanj	Orissa
No of Doors	2	2	3	-	-
No of Windows	1	1	1	-	-
No of Rooms	3	3	4	-	-
% Kuccha Houses	75	64	32	59.76	50.2
% Semi pucca Houses	25	25	48	33.18	27.6
% Pucca Houses	0	0	20	7.06	22.2
% Houses with electricity	0	0	12	15.71	26.9
% Drinking Water from Hand pump	0	28.57	36	22.59	28.5
% Drinking Water from open well	0	0	64	45.79	28.6
% Drinking Water from Streams	100	71.43	0	4.55	2.6

Land use and Agriculture in villages

The agriculture is the main source of livelihood in all these three villages. Agriculture/Forest land ratio is higher in Jenabil followed by Ghodabindha and Nawana. However, culturable waste land/agriculture and degraded land / agriculture land ratios are much higher in Nawana village. The crop output/input ratio is much higher in Jenabil village (Table 4). Paddy productivity of this village is comparable to central Himalayan village of Ubhayari (SINGH,1989). However, paddy productivity in Similipal is much lower than paddy productivity in tribal villages of Phulbani on Eastern Ghats of Orissa. Paddy (*Oryza sativa*) and Corn (*Zea mays*) are the principal grain crops and Niger (*Guizotia abyssina*) and Mustard (*Brassica nigra*) are main oilseed crops grown in these villages. Finger millet (*Eleusine coracana*) locally known as Mandia is

Table3. Details of different types of Land uses of Villages

Types of Land use	Jenabil	Nawana	Ghodabindha
Forest land (ha)	35.24 (25.30)	231.59 (42.91)	118 (40.33)
Agricultural land (ha)	74.61(53.56)	98.98 (18.34)	155 (52.98)
Culturable waste land (ha)	2.00 (1.44)	62.57 (11.59)	39 (13.33)
Degraded land (ha)	27.45 (19.71)	146.60 (27.16)	80.56 (27.54)
Total village area (ha)	139.30	539.74	292.56
Agriculture: forest land	2.12	0.42	1.31
Culturable waste: Agriculture	0.03	0.63	0.25
Degraded area: Agriculture	0.37	1.48	0.52

Values in parenthesis are in %.

grown in Jenabil only. Black gram (*Vigna mungo*) locally known as Biri (legume crop) is grown in all three villages. Tuber (mainly potato) is a cash crop and is grown in all villages. Various kinds of Vegetables locally known as Suturi, Kunnuru (*Boswella serrata*), Karala (*Momordica charantia)*, Jatia, Saru Tuber (*Colocasia esculenta*) and lady's finger (*Abelmoschus esculentus*) are also grown in these villages. The average seed input: crop output and crop output: crop input for all crops was higher in Jenabil than Nawana and Ghodabindha.

Table 4. Agricultural seed input, crop input (Kg/ha) and Output/input ratio in the study villages of Similipal Biosphere Reserve.

Parameters	**Jenabil**	**Nawana**	**Ghodabindha**
Seed Input /ha			
Paddy	101.09	103.89	133.19
Corn	36.65	16.74	7.99
Mandia	52.48	0	0
Niger	146.19	9.42	2.14
Mustard	50.53	8.14	0
Black gram (Biri)	48.73	1.57	2.28
Tubers	135.72	27.21	3.8
Fresh vegetables	4.66	0.15	3.09
Average of all crops	72.01 (± 18.91)	20.89 (± 13.13)	19.06 (± 17.43)
Crop Output/ha			
Paddy	786.71	280.28	584.05
Corn	886.73	520.58	71.54
Mandia	1311.99	0	0
Niger	1714.57	98.6	9.5
Mustard	902.41	104.6	0
Black gram (Biri)	191.31	63.83	21.84
Tubers	678.62	120.33	47.48
Fresh vegetables	96.36	18.57	71.94
Average of all crops	821.09 (± 201.38)	150.85 (± 64.90)	100.79 (± 74.52)
Output / Input ratio			
Paddy	7.78	2.69	4.39
Corn	24.19	31.09	8.95
Mandia	25		0
Niger	11.73	10.47	4.44
Mustard	17.86	12.86	0
Black gram (Biri)	3.93	40.67	9.58
Tubers	5	4.42	12.5
Fresh vegetables	20.68	122.22	23.31
Average of all crops	11.40	7.22	5.29

Energetics of agro-ecosystems

The agricultural crop inputs can be categorized into four types, as (a) Soil preparation inputs (b) Labour saving inputs (c) Yield increasing inputs and (d) Plant protection inputs (BURINGH,

Table 5. Agricultural Energetics and Carrying capacity of the study villages. (All input and output values are in GJ/ha/year)

ITEMS	**Jenabil**	**Nawana**	**Ghodabindha**
Total seed input	1.15 (20.21)	0.29 (4.29)	0.27 (2.32)
Man days	0.28 (1.39)	0.59 (13.75)	0.84 (36.18)
Women days	0.29 (5.10)	0.54 (7.99)	0.95 (8.17)
Animal days	1.18 (20.74)	0.6 (8.88)	0.75 (6.45)
Total labour	1.75 (30.76)	1.73 (25.59)	2.54 (21.84)
Chemical fertilizer	0.19 (3.34)	0.66 (9.76)	1.13 (9.72)
Cow dung	1.42 (24.96)	4.03 (59.62)	7.69 (66.12)
Total yield increasing input	1.61 (28.30)	4.69 (69.38)	8.82 (75.84)
Fence wood	1.18 (20.74)	0.05 (0.74)	0 (0)
Total crop protection inputs	1.18 (20.74)	0.05 (0.74)	0 (0)
Total energy input	5.69	6.76	11.63
Total agricultural energy output	14.64	2.41	1.32
Output/Input ratio	2.57	0.36	0.11
Rice consumption	5.79	1.53	6.51
Edible oil consumption	0.32	0.03	0.13
Total energy consumed	6.11	1.6	6.64
Fuel wood consumed	43.97	62.37	68.91
Kerosene consumed	1.28	0.98	2.39
ENERGY SOURCE	**Jenabil**	**Nawana**	**Ghodabindha**
Forests	45.15 (73)	62.42 (92)	68.9 (84)
Market	1.79 (3)	1.67 (2)	9.11 (11)
Human & Livestock	1.75 (2)	1.73 (3)	2.54 (3)
Agriculture	13.49 (22)	2.12 (3)	1.05 (2)
Total	62.18	67.94	81.6
Carrying capacity of Paddy (Persons/ha)	2.66	0.95	1.98
Carrying capacity of Corn (Persons/ha)	3.48	2.05	0.28

1985). The total yield is output from agricultural ecosystem. The seed and labour inputs increase as we move from periphery to core zone of Biosphere Reserve (Table 5). The Desi dhan (local paddy variety) is cultivated in core and buffer where as Sarakari Dhan(hybrid paddy varieties of Ratanagiri, Khandagiri and Konark) is cultivated in the peripheral village. Human and animals mainly form the agricultural labour. Labour saving input was absent in area. The manure and

chemical fertilizer form the main yield increasing inputs. The yield protection input was in the form of fencing the crop fields surrounding their huts.
The village Ghodabindha and Nawana have more or less similar seed input, labour input, yield increasing energy input and fuel wood consumption (Table 5). There is no crop protection input in Ghodabindha. Annual Fuel wood and kerosene consumption were much higher in Ghodabindha than other villages. The input and crop output and output/input ratio in terms of energy in Jenabil are much higher than other villages. The cow dung and chemical fertilizer inputs show decreasing trend while one moves form periphery to core. The Nawana and Ghodabindha have the maximum yield increasing inputs as chemical fertilizer and cow dung i.e. 69.38 % and 75.84 % of total input, respectively. High seed input observed In Jenabil was probably due to repeated crop failures as reported by villagers. Further, the seed input values of village Jenabil are higher on account of much higher input for Mandia, Mustard and Tuber crops. The animal labour was major energy source in Jenabil and Nawana while human labour forms the major source of energy in Ghodabindha.

Carrying capacity of villages

The carrying capacity of study village ecosystems was determined for Paddy and corn, using formula as $Ci = N_H / A_{CL}$ and $N_H = A_{CL}$ Pi Ei/365 R_H, where Ci is carrying capacity of ecosystem, N_H is Number of human beings supported by the ecosystems, A_{CL} is area of crop land, Pi is productivity of crop, Ei is energy content of crop and R_H is per capita nutritional requirement for human (REDDY,1981). The energy content value for crops was used following MITCHELL (1976) and for Nutritional requirement of humans (GOPALAN et *al*, 1982).

The carrying capacity of Paddy crop was calculated at 2.66 persons/ha in the core village using grain productivity of Paddy as 787 Kg /ha which is much less than 12.8 persons/ha (NISANKA & MISHRA,1990) and 8.6 persons/ha (REDDY,1981). The low productivity is the main cause of low carrying capacity in Jenabil (Table 5). The actual human density of Jenabil for total village area and for total cropped area is much less than the carrying capacity of paddy crop. The corn carrying capacity was calculated 3.48 persons /ha, using the grain productivity of corn as 280 Kg/ha. It becomes clear from the carrying capacity of paddy and corn that corn is much efficient crop to support more number of people in Jenabil as human density is much low than the maximum human being supported by the system.
The carrying capacity of Paddy crop in Nawana and Ghodabindha villages is higher than the actual human density and is lower than the total cropped area. A large area is under ‘forest’ or ‘area not available for agriculture’ in these villages. Corn carrying capacity is much higher than the human density and crop productivity. This village also indicates that corn is much efficient crop to support more number of people. There is a clear need to shift the crop pattern form paddy to corn in Nawana. The corn carrying capacity is far lower in Ghodabindha village than the actual human density and total cropped area. It becomes clear that among the carrying capacities of paddy and corn, none of the crops are efficient to support the actual human density in this village.

The core village Jenabil derives less energy from forests than other two villages of buffer and periphery. All the villages, however, derive more or less similar quantity of energy from human and livestock. Energy derived by Core village from agriculture is almost 7 times higher than other two villages. Total energy consumed by core and buffer villages ranged between 62 and 68 GJ/year, however, consumption in peripheral village is 81.6 GJ/year. It is evident that there is not much difference in pattern of total energy consumption in Jenabil and Nawana as both are much dependant on agriculture; however, Ghodabindha is dependant on market for 11 % of its energy requirement (Table 5).

We have excluded the forest energy as fodder and Minor Forest Produce (MFP) in the above calculations. The dependency of peripheral and buffer villages on these forests produce is high compared to core village. The core village Jenabil is highly dependant of agriculture and carrying capacity is also high enough to support existing human population. However, the dependency level of these villages on forests is higher compared to tribal villages(DASH & MISHRA,2001) of

Phulbani in Orissa but the pattern is similar to Bhogibandha village of Ganjam district (NAYAK et *al* 1993). The Average crop productivity of the villages is similar to that of Bhogibandha village.

CONCLUSION

We conclude that agriculture in core village is much more energy efficient than in buffer and periphery. Lack of transport makes them much more dependant on agriculture and Forest collections. Over all energy consumption is much higher in periphery and buffer as these have easy access to market and there are other population requirements. 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 (SINGH et *al*, 1984; RALHAN et *al*, 1991). Carrying capacity of similipal forests at present seems to be capable of supporting the core village agriculture. However, all effort is needed to strengthen the protection mechanism in forest blocks surrounding the buffer and peripheral villages, and involving the people of these villages in other forest based livelihood option other than agriculture. Intensification of food crop production systems in buffer and periphery villages may lead to further loss of many ecosystem functions of Similipal Biosphere Reserve affecting especially sustainable productivity and nutrient cycling which will ultimately result in continued degradation of carbon sequestration and biodiversity.

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Appendix 1 . Energetic values of various items used for villages.

Items	**Energetic value in KJ/gram**	**Energetic value in K Cal/Kg**	**Energetic value in K joules/Kg**	**Source**
Paddy	14.42	3444.79	14420	Gopalan et al.,1982
Corn	16.87	4030.07	16870	Gopalan et al.,1982
Niger	27.31	6524.09	27310	Gopalan et al.,1982
Mustard	22.65	5410	22650	Gopalan et al.,1982
Mandia	13.67	3265.63	13670	Gopalan et al.,1982
Biri	14.29	3413.74	14290	Gopalan et al.,1982
One Man day	11.72	2800	11720	Mitchel,1976
One women day	9.13	2180	9130	Mitchel,1976
One animal day	35.78	8548	35780	Mitchel,1976
Chemi-fertilizer	30.24	7224	30240	Mitchel,1976
Cow dung	7.3	1743	7300	Mitchel,1976
Fuel wood	19.71	4708	19710	Mitchel,1976
Kerosene	35	8361.15	35000	Chandola,1976
Edible oil	37.5	8958.38	37500	Gopalan. et al.,1982
Vegetables	2.4108	575.916012	2410.8	Mitchel,1982
Tubers	3.9564	945.144396	3956.4	Mitchel,1982