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Impact of Energy Flow on Dry Deciduous Forest of Barnawapara Wildlife Sanctuary of Central India

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ABSTRACT
The present paper, based on a study of five village ecosystems, assesses the energy flow in the forest villages of Barnawapara Wildlife Sanctuary of Central India, along with the impact of this energy flow on the surrounding forests. Energy requirements such as firewood, food, fodder, and kerosene in the villages were inventoried. Energy efficiency was determined by calculating output-input ratio. Paddy was cultivated as a single rainfed crop and except for rice all the food items in the villages were imported from the market. About 75-80% of the fodder and 95-100% of the firewood needs of the villages were met from the surrounding forests.
The use of firewood and kerosene in the study villages were 132 kg day^{-1} and 2 l day^{-1}. Firewood consumption was 185 x 10^5 KJ yr^{-1} ha^{-1} of cultivated land. Kerosene use ranged from 5 x 10^5 to 14 x 10^5 KJ yr^{-1} ha^{-1}. Fodder from the forests used for the livestock ranged between 324 x 10^5 to 606 x 10^5 KJ yr^{-1} ha^{-1} of cultivated land. The energy efficiency was 2.67 for all the cropped area. The illegal felling and lopping of trees was found to be increasing in concentric circles around the villages and together with grazing it resulted into a savanna like situation. The study calls for establishing fuel wood plantations (of fast growing species), and pastures (of legume and grass mixtures) for the conservation of forests. In addition, all possible encouragement for the reduction of livestock population needs to be given. Additionally, integration of fodder, fuel, and food production through agroforestry and silvipasture systems needs to be experimented with and duly popularized. By the introduction of efficient wood-burning stoves it should be possible to reduce the fuel-wood consumption in the villages. Possibilities of substitution of fuel-wood by other sources of energy - such as solar energy and kerosene - should also be taken into consideration.

Key words: Energy flow, Energy efficiency, Firewood, Fodder , Livestock, Forest degradation

INTRODUCTION

Forests have been a source of livelihood for rural population in India over the ages. Many plant species are used for domestic needs by the local communities. About 124 plant species are used by the people living in the forest villages of Madhya Pradesh (Central India) for firewood, fodder and medicinal purposes (Purushothaman et al. 2000). Overharvesting of forest resources has a drastic effect on the forests throughout India (Anitha et al. 2003, Rai and Chakrabarti 2001). Species diversity, stem densities and the regeneration of targeted species were lower in heavily impacted forests as documented by Murali and Hedge (1996), Murali et al. (1996), Sekar (1999), Shanker et al. (1998). This has resulted in the degradation and loss of forest cover and biodiversity (Garrigues 1999, Pouchepadass and Puyravaud 2002, Silori and Mishra 2001).

Deforestation caused by the development has affected the natural forest ecosystems world over as well as India, causing potentially serious, long-term effects on regional edaphic and hydrologic characteristics. Hansen et al. (1981) pointed out that the expected increase in global temperature due to exacerbated greenhouse effect may cause widespread changes in precipitation pattern, its quantity and intensity. In several places, the forest has degraded to savanna, grassland, and wasteland. Extension of agriculture at the expense of forest has occurred. Conversion of dry tropical Indian forest to savanna and agricultural land are reported to result in the loss of about 45% to 51% soil carbon (Srivastava and Singh 1991). In many areas the subsistence agriculture is subsidized by the energy inputs from surrounding natural vegetation (Singh et al. 1984, Pandey and Singh 1984a, Singh and Singh 1989), and this may constitute a major cause of gradual deterioration of forests and the soils that support them (Singh and Singh 1991). From a study on energy budget of some multiple cropping patterns of the Central Himalaya Sharma (1991) has inferred that multiple cropping patterns are more efficient in rainfed than in irrigated conditions. An investigation on the energy use in relation to yield of traditional crops in central Himalaya revealed that the total energy inputs and outputs are higher for irrigated agriculture than rainfed system (Chandra et al. 2021). Singh et al. (2021) have documented the forest resource utilization in some villages of Pauri Garhwal, Uttarakhand and have emphasized the conservation of tree species needed for the fodder and fuelwood. Rastogi et al. (2018, 2019) have studied the energy flow through summer cropping in a mountain agro-ecosystem of Kumaun Himalaya. Chandra et al. (2011) have documented the agrobiodiversity management in the central Himalayan village ecosystem and have found higher biological and economic yield in mixed cropping compared to sole cropping. In another study Chandra et al. (2021) have studied the impact of farm yard manure on cropping cycle in a rainfed agroecosystem of Central Himalaya.

This study intends to show that the villages in the vicinity of the forests are dependent for energy on the surrounding forests. Analyzing the flow of energy through a forested ecosystem or a society is useful in describing system functioning (Loucks and D'Alessio 1975). According to Mitchell (1979), agriculture in India is solar driven as most of the activities are supported by the solar energy stored in crops and cycled through livestock and people.

The present paper, based on a study of five village ecosystems, assesses the energy efficiency of rain-fed agriculture in a dry tropical environment and its impact on agricultural activity and the surrounding natural ecosystems. Energy flow in the forest villages of Barnawapara Wildlife Sanctuary of Central India, along with its impact on the surrounding forests have been assessed and documented. We explore the relationships between energy flow of forest and forest villages of a forested landscape. This study adopted an approach given by Pandey and Singh (1984a,b) who examined the energy flow relationship between agro and forest components of forested ecosystems in the central Himalaya. Singh and Singh (1992) used the same approach for forest villages of dry deciduous forests of India. The aim of this investigation was to assess: (i) the energy flow relationship between village and surrounding natural forests, and (ii) the extent of energy consumption by the forest villages.

MATERIAL AND METHODS

Study area

The study was carried out at Barnawapara wildlife sanctuary of Barnawapara range of Baluada Bajar Forest Division (Chhattisgarh) during the years 2006-2009. The study area is located between 21^{0}20'0" to 21^{0}25'47" North latitude and 82^{0}21'17" to 82^{0}26'27" East longitude in the north-eastern part of Raipur district, Chhattisgarh, India (Fig. 1). The study area is located at 463 m above the mean sea level. The climate of the area is described by Singh (2007), which is dry humid tropical with three seasons in a year: rainy (mid-June to September), winter (November to February) and summer (April to mid-June). October and March comprise transition periods between rainy and winter, and between winter and summer, respectively. The average annual rainfall ranges from 1200-1350 mm. About 80% of the annual rainfall is received from southwest monsoon during June to September. The mean annual maximum and minimum temperatures are 33.1^{0}C and 20.5^{0}C, respectively. Rainfall and temperature data is based on Baluada Bajar Forest Division (Chhattisgarh) office record.

Champion and Seth (1968) classified the forests of the experimental area into four major types viz., Southern Tropical Dry Deciduous Teak forest (5A/C1b), Northern Tropical Dry Deciduous Sal forest (5B/C1c), Northern Tropical mixed Deciduous Sal forest (5B/C2) and Dry Bamboo Brakes (5/E9). In the Barnawapara wildlife sanctuary northern and eastern areas have dense forests, whereas Teak plantations are common in the southern side. The western areas have mixed and degraded forests and occupy a large area in addition to bamboo which occurs in patches. The common species in the sanctuary are: *Shorea robusta, Anogeissus latifolia, Adina cordifolia, Acacia catechu, Mytragyna parviflora, Lagerstroemia parviflora, Diospyros*

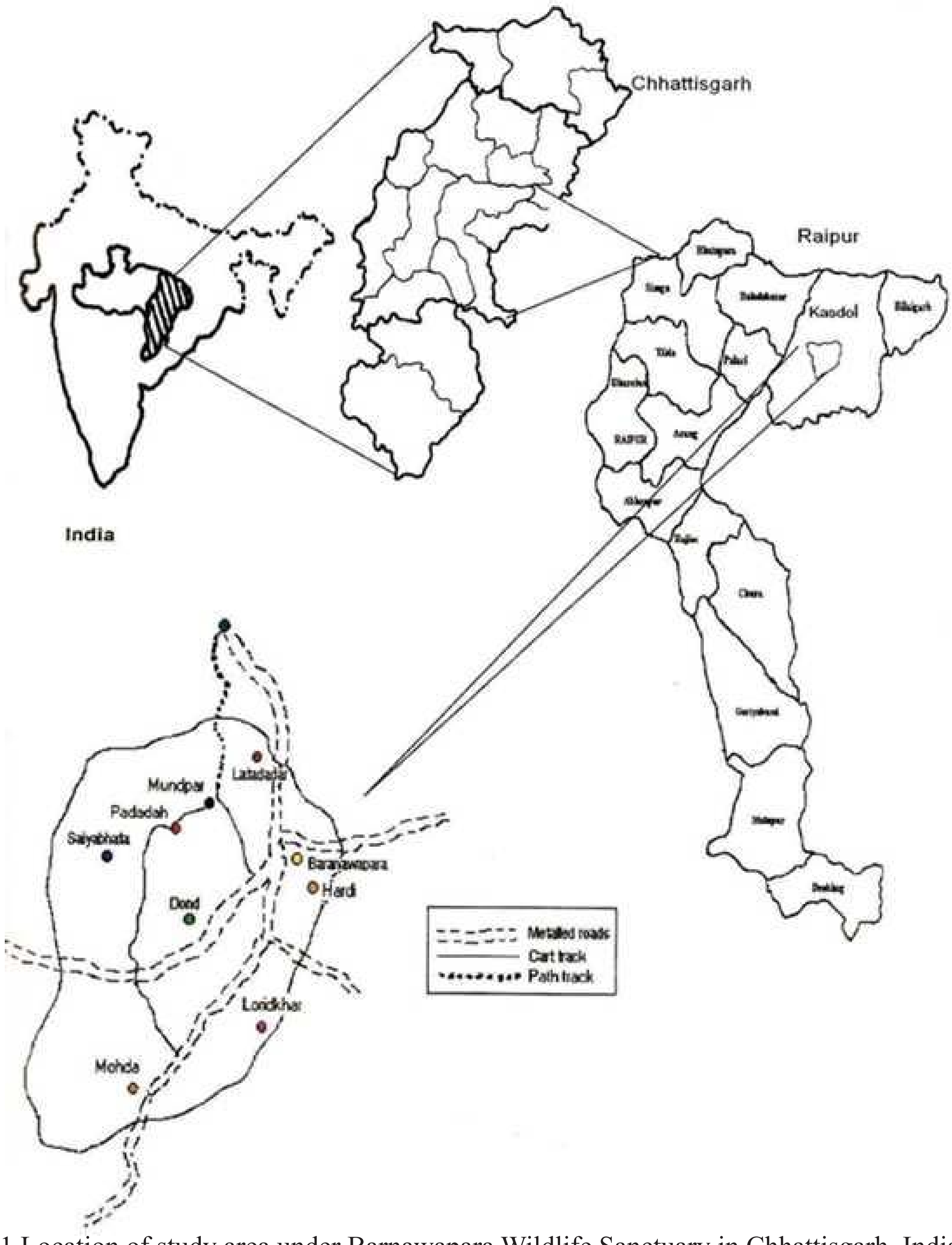

Figure 1 Location of study area under Barnawapara Wildlife Sanctuary in Chhattisgarh, India

melanoxylon, Tectona grandis, Madhuca indica, Terminalia alata, Terminalia tomentosa, Buchanania lanzan, Bridelia retusa, Semecarpus anacardium, Cleistanthus collinus, Pterocarpus marsupium, Schleichera oleosa, etc. (Singh et al. 2009, Sahu et al. 2013, Bargali et al. 2014).

Methods

Five villages, namely, Bafra, Gudagarh, Bhimouri, Deogaon and Hardi were selected for the present study. These villages represent the soil and geological conditions of the region and cover the range of landscape variations. The villages have three main components; humans, livestock and cropland. These three components participate and maintain the energy flow relationships with the surrounding natural forests and the market (Pandey and Singh 1984a). A house-to-house survey was made in the selected villages and a complete inventory of the following was made for each village: (1) total area under crops, (2) cropping pattern (mono or multicropping), (3) labour input in terms of human and bullock-days, (4) manure input in agriculture fields, (5) fertilizer input in agriculture fields, (6) seed input while sowing, (7) yield of crop and crop byproducts, (8) sources and requirement of fuel/firewood for humans, (9) sources and requirement of fodder for livestock, (10) family structure, and (11) size of livestock population. The inventory was based on inquiries made from the villagers in a house-to-house survey which includes adult men or women from each family and repeated field checks over a three-year period, which included weighing of head loads of firewood and fodder brought by the villagers from the adjoining forests. The input values were calculated in terms of human and bullock power and the quantities of seed and manure used in cultivated areas. The output was calculated as agronomic yield of crops and crop byproducts. All the data collected as input and output were converted into energy by multiplying the quantities with standard values reported by Mitchell (1979) and Pandey and Singh (1984a,b) (Table 1). The energy efficiency of each crop system was calculated as the output-input ratio. Data are mostly presented on the basis of per hectare of cultivated land.

Table1. Calorific value on fresh weight basis for agricultural materials (based on Mitchell 1979, Pandey and Singh 1984a,b).

Category	KJ kg^{-1}
Grains	16,233.0
Pulses	17,094.0
Green fodder	3,956.4
Tree and shrub leaves	4204.6
Straw	13986.0
Manures	7,320.6
Fertilizer	30340.8
Milk	4254.60
Firewood [a]	16,700.00
Kerosene [b]	46,498.00
Labor	**KJ day^{-1}**
One man-day	16,710.00
One bullock-day	72,744.00

[a] Energy values are on oven-dry weight basis.
[b] 0.82 litres of kerosene = 1 kg.

RESULTS AND DISCUSSION

Cropping pattern

The study villages followed a mono cropping pattern having only one crop in a year. Nearly all the crop fields were covered by rainfed paddy, sown as kharif crop in the month of July and harvested in October. After harvesting the paddy crop, the land remains uncultivated (fallow) due to lack of irrigation facilities for about 8 months in a year. Single cropping was practiced in 40 ha at Bafra, 45 ha at Gudagarh, 33 ha at Bhimouri, 35 ha at Deogaon and 63 ha at Hardi. All the pulses required for households, mainly Tiwra (*Lathyrus sativa*) and Urd (*Vigna mungo*), were purchased from the market.

Energetics of crop production and energy efficiency of agroecosystem

Croplands

For the paddy crop, input and output values and the output-input ratio were calculated in terms of energy. Area weighted mean values for inputs and outputs were calculated for the year on the basis of per hectare cultivated area (Table.2). Annual input of energy in the form of human and bullock labour was highest (5.6 x 10^5 and 13.1 x 10^5 KJ yr^{-1} ha^{-1} cultivated land) for Bhimouri and lowest (2.43 x 10^5 and 3.76 x 10^5 KJ yr^{-1} ha^{-1} cultivated land) for Deogaon. In the form of seed and manure, energy input was highest (15.8 x 10^5 and 259.6 x 10^5 KJ yr^{-1} ha^{-1} cultivated land) for Bafra and lowest (7.8 x 10^5 and 128.8 x 10^5 KJ yr^{-1} ha^{-1} cultivated land) for Gudagarh. Annual energy input in the form of chemical fertilizer was high (27.6 x 10^5 KJ yr^{-1} ha^{-1} cultivated land) for Bafra and low (9.6 x 10^5 KJ yr^{-1} ha^{-1} cultivated land) for Deogaon.

The agronomic output was obtained in the form of paddy grain and straw. The highest grain and straw yields were respectively, 374.6 x 10^5 and 488.4 x 10^5 KJ yr^{-1} ha^{-1} cultivated land, for Bhimouri; and lowest grain and straw yields were 179.2 x 10^5 and 221.9 x 10^5 KJ yr^{-1} ha^{-1} cultivated land for Gudagarh. The highest agronomic yield (grain + straw) was 863 x 10^5 KJ yr^{-1} ha^{-1} cultivated land for Bhimouri and the lowest (401.1 x 10^5 KJ yr^{-1} ha^{-1} cultivated land) for Gudagarh. The output per unit of input ranged from 2.47 to 2.88. The average output-input ratio for entire agro-ecosystem was 2.67 (Table 2).

The human population per hectare of cultivated land, total minimum food energy requirements for people, food grains and agronomic yield from the croplands of these villages are given in Table 3. The minimum requirement (maintenance energy plus that required for a medium level of activity) for the people was calculated as the average across age groups, following Mitchell (1979). The value is 12249 KJ per adult individual per day and 7942 KJ per child per day plus 6228 KJ as increment for labor on working days.

Subsidy from natural forests

The livestock population per hectare cultivated land and fodder requirement and source for the five forest villages are presented in Table 4. About 75%-80% of the total fodder requirement was met from the surrounding natural forests. Paddy straw contributed 20% - 25% of fodder need. Foliage from *Cleistanthus collinus, Ziziphus mauritiana, Dalbergia sissoo, Ficus benghalensis, F. religiosa,, Cordia dichotoma, Helicteres isora* was used as fodder in Bafra, Gudagarh, Deogaon and Hardi villages.

The firewood, fodder and kerosene use in the five forest villages are presented in Table 5. The tree species commonly preferred for fire-wood are *Anogeissus latifolia, Ziziphus glaberrima, Lagerstroemia parviflora, Hardwickia binata, and Ziziphus mauritiana.* Occasionally, *Boswellia serrata* and *Adina cordifolia* are also used for fire-wood.

Average consumption of firewood, fodder and kerosene in five forest villages was 131 kg per day, 893 kg per day and 2 liter per day, respectively. Most of the collected firewood was used by the villagers and it was not marketed.

Table 3. Human food energy requirement, agronomic output and import of food grains in the five agro-ecosystems (x 10^5 yr^{-1} ha^{-1} cultivated land)[a]

Village	AC	HPC	FER[b]	AO	IF
Bafra	40	8.27	829.3	359.15	21.47
Gudagarh	45	9.6	2570.06	168.46	20.6
Bhimouri	32.5	10.27	1127.06	374.6	24.24
Deogaon	35	5.14	1645.26	263.9	11.72
Hardi	62.5	5.71	574.3	301.5	13.33
Average	43	7.79	1349.19	293.52	18.27

AC= Area of cultivation (ha); HPC = Human population per ha of cultivation; FER = Food energy requirment; AO = Agronomic output; IF = Import of foodgrans

[a] One man-day = 6 h.

[b] Calculated by taking maintenance energy as 12,249.3 KJ per adult per day and 79420 KJ per child per day plus 6228 KJ as increment for work on working days

Table 2. Annual energy budget for agriculture in the five forest villages in (x 10^5 KJ yr^{-1} ha^{-1} cultivated land)

	Study villages					
	Bafra	**Gudagarh**	**Bhimouri**	**Deogaon**	**Hardi**	**Mean**
Input						
Human labor	3.8	3.43	5.6	2.43	2.65	3.58
Bullock labor	7.2	10.1	13.1	3.76	9.1	8.65
Seed	15.8	7.8	12.96	9.46	12.83	11.77
Manure	259.6	128.8	252.7	189.8	170.07	200.19
Chemical fertilizer	27.6	12.03	24.5	9.6	10.5	16.84
Total	**314**	**162.16**	**308.86**	**215.05**	**205.15**	**241.04**
Output						
Grain production	359.1	179.2	374.6	263.9	301.5	295.66
Crop residue	456.9	221.9	488.4	307.2	291.3	353.14
Total	**816.14**	**401.1**	**863**	**571.1**	**592.8**	**648.8**
Output-input	2.59	2.47	2.79	2.65	2.88	2.67

Table 4. Livestock requirement (ha^{-1} of cultivation) and sources of fodder for the five forest villages (x 10^5 KJ yr^{-1} ha^{-1} cultivated land)

Village	Livestock per ha cultivation	Total requirement of fodder	Available fodder		Percent of fodder requirement
			Source	Amount	
Bafra	6.62	344.39	Tree & shrub leaves	3.06	0.88
			Grazing	232.86	67.61
			Crop residue	108.47	31.49
Gudagarh	6.17	380.5	Tree & shrub leaves	3.75	0.98
			Grazing	279.18	73.37
			Crop residue	97.57	25.64
Bhimouri	8.7	605.65	Grazing	490.98	81.07
			Crop residue	114.67	18.93
Deogaon	4.05	385.08	Tree & shrub leaves	6.13	1.59
			Grazing	317.69	82.49
			Crop residue	61.26	15.98
Hardi	5.24	323.79	Tree & shrub leaves	7.85	2.42
			Grazing	248.15	76.63
			Crop residue	67.79	20.93
Average	6.17	407.88	Tree & shrub leaves	4.16	1.17
			Grazing	313.77	76.23
			Crop residue	89.95	22.59

Table 5. Total consumption of energy in the forest villages

Forest village	Fuelwood			Fodder		Kerosene	
	kg day^{-1}	Kg day^{-1} $capita^{-1}$	KJ x 10^2 @16700 KJ/kg*	kg day^{-1}	KJ x 10^2 @3956.4 KJ/kg *	l day^{-1} @46498 KJ/kg	KJ x 10^2
Bafra	114	0.34	19038	645	25518.78	2.6	1474.32
Gudagarh	142	0.32	23714	870	34420.68	2.5	1417.62
Bhimouri	132	0.4	22044	1105	43718.22	1.75	992.33
Deogaon	61	0.33	10187	770	30464.28	0.865	490.49
Hardi	209	0.6	34903	1074	42491.73	2.84	610.41
Average	**131.6**	**0.4**	**21977.2**	**892.8**	**35322.73**	**2.11**	**1197.03**

*Mitchell (1979) (0.82 liters of kerosene =1 kg)

Energy flow from agricultural systems and its impact on natural forests

The mean annual energy flow in the five forest villages are presented in Figure 2. All calculations were done on the basis of per hectare of cultivated land. The total firewood and fodder related energy accessed from the forests per hectare of cultivated land for the five forest villages averaged 502 x 10^5 KJ yr^{-1} (184.7 x 10^5 KJ firewood energy and 317.3 x 10^5 KJ fodder energy).The annual input per hectare of cultivated land was 743 x 10^5 KJ yr^{-1} (which includes 241 x 10^5 KJ agricultural inputs in the form of seed, organic manure, chemical fertilizer and human and bullock labour; 184.7 x 10^5 KJ fuelwood and 317.3 x 10^5 KJ fodder) against the output (rice grain and paddy straw) of 648.8 x 10^5 KJ (295.66 x10^5 KJ food grain and 353.14 x 10^5 KJ paddy straw) per year per hectare of cultivated land. The input-output ratio for cropland thus was 1.14 indicating that 1.14 units of energy are utilized to obtain one unit of energy as agronomic yield. This ratio (4:1) was higher for the other forest villages of dry deciduous forest region of northern India (Singh and Singh 1992). As the agronomic output is not sufficient to meet the family requirements, majority of villagers migrate to other states for livelihood options as they follow only single cropping system. Present observations show that these villages are centers of enormous energy consumption causing a huge pressure on the surrounding natural forest. The croplands can remain viable as long as the energy subsidy in the form of fodder and firewood from the surrounding forests continues to be available. Nayak et al. (1993) studied the biomass and energy dynamics in a tribal village ecosystem of Orissa in India and reported that villages are mostly forest-dependent.

Collection of firewood (Fig. 3) and tree leaves is made through illegal felling and lopping of trees resulting in blank areas. Increasing blank areas and the encroachment of the forestland around the villages gradually result in expansion of village areas and reduction in forested areas. Unsustainable extraction of forest resources (such as firewood) has caused loss of forest and wildlife habitats (Jha 1999) as well as loss of species diversity (Kakati 1999, Ramesh 2003, Verma et al. 1997). Ever-increasing concentric circles of forest destruction are evident

Figure 3. Heavy collection of firewood from forest as head and cycle loads

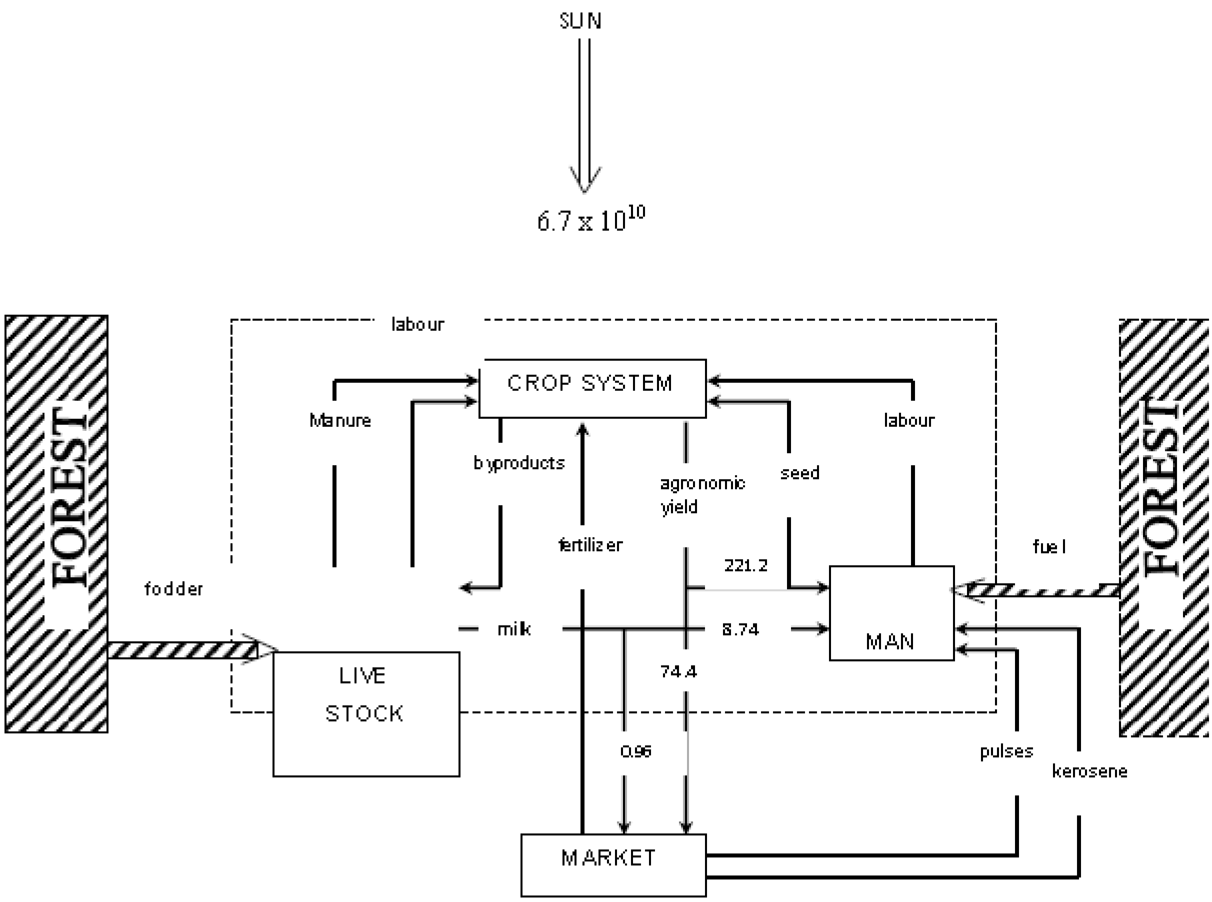

Figure 2. Energy flow through the croplands. Values are means from five villages (x KJ ha^{-1} yr^{-1} cultivated land); solar radiation = 6.7 x 10^{10} KJ ha^{-1} yr^{-1}

Figure 4. Excessive and free-range grazing causes a huge impact on the regeneration of vegetation

around each of the villages. Excessive grazing (Fig. 4) limits the regeneration of woody elements that results into formation of savanna like situation. Forest degradation in protected areas caused by livestock grazing can also reduce wild herbivore population (Madhusuddan 2004, Silori 2001).

Raghubanshi et al. (1991) have reported nearly 40.15% of the total forest area conversion from mixed forest with crown cover >50% to a mixed forest with crown cover <50% - 30% between 1984 and 1989. They (Raghubanshi et al. 1991) reported that good to poor forest conversion occurred at a rate of 6.59% of the forested area per year and savanna formation took place at a rate of 3.29% per year. The conversion of forest to agricultural land causes the loss of soil and microbial nutrients.

CONCLUSION

The present study analyzed the energy budget for croplands, forest villagers and their livestock in five forest villages of Barnawapara wildlife sanctuary. These village systems depend to a great extent on the surrounding natural forests for their energy requirement. A considerable amount of subsidy was accessed from surrounding natural forests in terms of wild edible products, fodder and firewood. Farmers of these villages grow paddy crop in a single cropping in their limited land holdings (2.5 ha per family). As the agronomic output was not sufficient to meet the family requirements throughout the year, many people migrate elsewhere in search of livelihoods and their remittances become an important source of money enabling the families to buy household items from the market.

From the forest management point of view, the use of firewood needs to be brought down in order to limit the cutting of trees and shrubs for enabling better regeneration of natural forests. Imposing a ban on the firewood collection would be impractical in view of the total dependence of villagers on the forests. Therefore, phase wise introduction of alternate fuel would help in bringing down the dependency of local villagers on biomass resources. In these villages, a majority of the population has agriculture-based economy, therefore the use of dung cakes, agriculture residues and biogas could be promoted. In addition, plantation of firewood species on the bunds of agriculture fields could help in meeting the firewood demand of the families who may not afford the cost of biogas. Awareness programmes can also be taken up in these villages towards the sustainable use of existing and introduced conventional and non-conventional energy sources.

A restoration programme can be initiated in the degraded dry forests adjoining these villages. Planting has to be undertaken to maintain a surplus plant cover for environmental conservation to keep pace with tree removal. The state forest department should play active role in initiating the awareness programme among villagers as well as programme for restoration of the degraded forests.

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