Biomass and Bioenergy Vol. 1, No. 2, pp. 99–109, 1991
Printed in Great Britain.

ENERGY PROFILES OF THREE UN-ELECTRIFIED VILLAGES IN EASTERN UTTAR PRADESH OF INDIA

RANJAN KUMAR BOSE,* CHARU PURI† and VEENA JOSHI*
*Tata Energy Research Institute, 7 Jor Bagh, New Delhi-110 003, India
†Centre for Rural Development and Appropriate Technology, Indian Institute of Technology, Hauz Khas, New Delhi-110 016, India

(Accepted 15 February 1991)

Abstract—A comparative analysis of the village level energy consumption pattern of different end-uses in the three un-electrified villages of India located in different districts of eastern Uttar Pradesh, is presented based on a census survey of households. This empirical study examines how the energy consumption pattern in the three villages—Maulaganj, Arro and Bishnapur—representing agriculturally advanced, moderate and backward economic categories, respectively, are influenced by the locally available biomass energy resources. The study reveals that in these villages the share of biomass fuels in the total energy consumed for domestic activities is as high as 98%. In agriculture, the share of animate energy is in the range of 70–100%.

Major findings in the domestic sector are: (i) firewood (logs and twigs), where easily available, is preferred to crop residues and dungcakes for domestic energy consumption; (ii) easy availability of wood encourages excess consumption; (iii) 18–42% more useful energy is consumed in winter than in summer for meeting cooking and water heating needs.

Major findings in the agricultural sector are: (i) the agriculture practised in village Bishnapur is totally traditional (100% based on animate power) and this is reflected by lower yields of the two major crops, viz. wheat and paddy as compared to the other two villages; (ii) in spite of the higher diesel consumption for land preparation and irrigation in village Arro the yields of wheat and paddy are nearly double in village Maulaganj suggesting it has more productive land.

Keywords—Rural energy, biomass resources, energy consumption, household, agriculture, crop productivity.

1. INTRODUCTION

In India, rural households depend on locally available biomass resources for meeting their domestic energy needs.[1–3] Other than the biomass energy resources which consist of wood fuels, agricultural residues and cattle dung, modern fuels like kerosene, diesel and electricity are also used at the village level. How much of a particular fuel is used in a household depends on the availability of that fuel and several factors that determine the household's capacity to buy/exchange/grow/gather the fuel. These factors are cash income, income-in-kind, the family size and composition, cropping pattern, yield, and livestock ownership. It is important to understand the linkages between energy consumption and resource availability for appropriate energy planning in rural areas.

The Tata Energy Research Institute (TERI), New Delhi, has, over the past five years, conducted a number of village level energy surveys to understand the linkages between consumption and supply of energy resources.[4–9] This paper presents a comparative analysis of rural energy consumption patterns and the resource potential of three un-electrified villages in Uttar Pradesh state, surveyed during 1986. The three villages are: Maulaganj in Gorakhpur district,[5] Arro in Pratapgarh district[6] and Bishnapur in Bahraich district,[7] all located in a Tarai* region of eastern Uttar Pradesh. This study examines how the energy consumption pattern in these three villages—representing agriculturally advanced, moderate and backward categories, respectively—is influenced by the locally available biomass energy resources.

2. MATERIALS AND METHODS

The methodology of this study consisted of three steps: selecting the villages, data collection at village and household level, and analysis of the data.

*The low lying areas near the foothills of Central Himalayas.

2.1. *Village selection*

The three villages Maulaganj, Arro and Bishnapur were identified in consultation with officials of the Uttar Pradesh State Electricity Board (UPSEB) and the Planning Research and Action Division (PRAD) in Lucknow. A number of parameters were used for selecting the villages: (i) unelectrified, with no possibility of electrification in the near future; (ii) different degrees of economic development; (iii) population size not to exceed 1500; (iv) income disparity between any two groups of households should not be very large; (v) easy accessibility; (vi) common cropping patterns; (vii) similar livestock patterns; (viii) different levels of mechanization; and (ix) good public co-operation.

2.2. *Data collection*

Two university postgraduates familiar with the selected villages and the local language were selected for data collection from village and household levels. They were trained to collect data by the method of users' recall for the preceding summer and winter months in the domestic sector and the last two cropping seasons of 1985–86, viz. *kharif* (October 1985–March 1986) and *rabi* (April–September 1986) in the agricultural sector. The method of recall was selected for data collection in preference to measurement so that more interviews could be held in the same time to obtain more information. This we hoped would average out biases, if any.

A questionnaire was designed for carrying out a survey to collect information on energy consumption and the variables likely to influence the type and level of energy consumed. The data was to be collected at two levels—the village and the household.

The village questionnaire was to elicit information about the village profile from the block and village level officials and also members of the Panchayat who are elected members of the village local body. At the time of data collection, group interviews of the village folk were also taken. Table 1 lists the parameters on which information was sought.

At the household level, the questionnaire was designed to gather information on the linkages between availability of energy resources and consumption. The important variables on which data was collected at the household level are also listed in Table 1. The questionnaires were pre-tested in Bishnapur village. Based on the feedback received, they were modified. Considerable difficulties were faced in eliciting information in standard physical units of biomass consumption for fuel purposes. Hence, we resorted to collecting information in local units. For example, the users found it easy to report headloads of wood used in a week which were later converted to kg of wood on a daily basis by measuring the quantity of wood in a typical headload.

Data was collected from all the households (188 households in Maulaganj, 135 in Arro and 92 in Bishnapur) in the three villages during the winter months (October 1986 through January 1987). The investigators visited each of the households only once and spent nearly 30–45 min on filling up the household schedule.

Table 1. Information items covered in the survey

Village schedule
Location of the village
General characteristics—distance from the block, status of irrigation, etc.
Demographic characteristics—population, number of households
Land particulars—distribution into cultivable land, forests, pastures, community land, etc. and also size distribution into number of households with large farms, medium farms, marginal farms and landless
Crops sown
Types of animals
Fuel types
Household schedule
Demographic details
Land particulars—cultivable land, irrigated land
Crop particulars—type of crops, yield, area under irrigation
Livestock particulars—number of animals, dung output by animal type
Domestic energy consumption
—Consumption of dung, crop residues, firewood, twigs, branches, and kerosene for different end uses viz. cooking and water heating, space heating and lighting. This data was collected for summer and winter months to capture seasonal variations
Agricultural energy consumption
—Data on the crops sown, area under each crop, time spent on land preparation, human, animal and energy inputs for both the activities

2.3. *Data analysis*

The survey data was tabulated and consistency checks were carried out by using a plausible range of values for each parameter.

We have estimated—cropwise—total crop residue production by using the standard residue to grain ratio[10] and their utilization pattern from survey data. The use of crop residues has been subdivided into three categories—crop residues used as fuel, fodder and thatching of a household, depending on the type of crops grown.

The total animal residue (wet dung) produced in these villages is calculated on the basis of dung output by draught and milch cattle. Data was collected on all relevant animals. The total availability of dung after deducting its non-fuel uses (such as fertilizer, building material) provided an estimate of the dung availability. For estimating the weight of dry dungcake consumption data was collected from all the households on the number of dungcakes consumed daily for different domestic activities using the method of recall. The average weight of a dry dungcake was measured in 10% of randomly selected households.

A variety of energy sources are consumed in both the domestic and agricultural sector. In order to facilitate aggregation of these fuels for a comparative analysis, all the physical units were converted into a common energy unit.

3. RESULTS

3.1. *Village profile*

Table 2 presents profiles of the un-electrified villages Maulaganj (M), Arro (A) and Bishnapur (B) based on the information gathered at the village level.

Table 2. Features of the three un-electrified villages in Eastern Uttar Pradesh*

Description	M	A	B
1. Village	Maulaganj	Arro	Bishnapur
2. Block	Paniyara	Rampur Khas	Mohin Purva
3. District	Gorakhpur	Pratapgarh	Bahraich
4. Population	1143	994	931
Children (% of total population)	52	51	55
Average family size	6	7	10
Sex ratio (Male:Female)	57:43	54:46	52:48
5. Operational landholdings: Total	188	135	92
% of households			
Large Farmers (>4 ha)	2	3	10
Medium Farmers (2–4 ha)	4	6	21
Small Farmers (1–2 ha)	14	22	20
Marginal Farmers (≤1 ha)	66	47	8
Landless	13	23	42
6. Livestock population	274	305	615
Young draft animals	70	10	3
Adult draft animals	4	51	30
Young milch animals	19	11	16
Adult milch animals	7	28	51
7. Number of diesel operated agricultural implements			
Tractors	2	2	—
Pumpsets	9	4	—
Threshers	8	9	—
8. Source of drinking water			
Tubewells	15	22	8
Water taps	—	—	12
9. Land utilization pattern (ha)			
Total land owned	320	132	190
Net cultivated area: Rabi	220	60	175
Kharif	146	102	185
Net irrigated area: Rabi	205	60	0
Kharif	137	102	0
10. Type of crops grown	Paddy Arhar Groundnut Wheat Mustard Lentil Gram	Paddy Wheat Mustard	Paddy Maize Wheat Mustard Lentil Gram

*Compiled from Refs 5, 6 and 7.

Table 3. Cropping pattern, area and yield of crops in the three villages

Crop name (botanical name)	Area (ha) M[a]	A[b]	B[c]	Yield ($100\ kg\ ha^{-1}$) M	A	B	All India[11] (1985–86)
Rabi Crops							
1. Wheat	99.55	56.25	74.06	21.99	11.86	9.39	20.32
Triticum aestivum	(100)	(100)	(0)				
2. Mustard	57.47	18.21	27.11	3.71	1.24	4.45	—
Brassica juncea	(100)	(100)	(0)				
3. Lentil	17.81	—	56.66	5.68	—	6.18	—
Lens esculenta	(99)		(0)				
4. Gram	25.50	—	16.59	6.18	—	4.20	7.43
Cicer arietinum	(99)		(0)				
5. Pea	19.02	10.52	—	3.21	2.72	—	—
Pisum sativum	(100)	(100)					
Kharif Crops							
6. Paddy	124.24	100.77	93.48	31.38	14.33	13.59	15.68
Oryza sativa L.	(100)	(100)	(0)				
7. Maize	—	—	74.87	—	—	6.18	11.72
Zea mays L.			(0)				
8. Arhar[d]	12.14	1.21	—	6.18	0.74	—	—
Cajanus cajan	(53)	(100)					
9. Groundnut	9.31	—	—	6.92	—	—	7.59
Arachis hypogea	(49)						

Note: Figures within parentheses indicate percentage of the total area.
[a]Maulaganj.
[b]Arro.
[c]Bishnapur.
[d]It is a pulse crop.

The village Maulaganj has the largest population (1143) followed by Arro and the smallest being Bishnapur (931). However, the average family size in Bishnapur is the highest (10). In Arro and Maulaganj, the family sizes are 7 and 6, respectively. The largest group of households in Bishnapur is landless; in the other two villages, it consists of marginal farmers. Village Maulaganj is endowed with more land (0.28 ha $capita^{-1}$) than Bishnapur and Arro. The animal density in Bishnapur is the highest (3.2 animals ha^{-1}), followed by Arro with the least being in Maulaganj (0.7 animals ha^{-1}).

In agriculture, paddy is the commonly grown crop in the kharif season in the three villages while in the rabi season, wheat and mustard are grown. In Bishnapur and Maulaganj, intercropping is done during the rabi season. The intercropping is done as follows: (i) wheat and gram, (ii) wheat and mustard, (iii) mustard and gram, and (iv) mustard and lentil. In Bishnapur, farmers do not use modern agricultural implements. In the other two villages, tractors, diesel pumpsets and threshers are extensively utilized. As far as cooking fuels are concerned, small quantities of kerosene are used only in Maulaganj in addition to biomass.

*Arhar is a pulse crop.

3.2. *Cropping pattern and productivity*

The area and yield of various crops grown in the three villages for the rabi and kharif seasons are presented in Table 3. For a comparative analysis, average productivity at the national level for each of the crops grown in the villages is also provided. It is seen that the productivity of most of the crops is less than the national average except for wheat and paddy in Maulaganj and lentil in Bishnapur.

3.3. *Availability of biomass resources*

3.3.1. *Crop residues.* The crop residues which are used as fuel are straw from mustard, lentil, gram, maize and arhar* and also groundnut shells. On the other hand, paddy husk, wheat straws, maize cobs and groundnut oil cakes are used for fodder. Besides this, paddy straw is also used for thatching the roofs of houses in all three villages. Table 4 summarises the total grain production and availability of various crop residues for different applications in the three villages.

3.3.2. *Dung.* Table 5 shows that the average daily wet dung production per animal is the highest for buffaloes, ranging from 8.1 kg to 8.9 kg. In the case of bullocks, daily dung production per animal ranges from 5.5 kg to

Table 4. Grain and crop residue production and residue utilization

	Annual grain produced (100 kg)			Residue/grain ratio[10]				Total residue (100 kg) available as: Fuel			Fodder			Thatching		
	M[a]	A[b]	B[c]	Straw	Husk	Cob	Shell	M	A	B	M	A	B	M	A	B
Rabi crops																
Wheat	2182	663	691	1.50	—	—	—	—	—	—	3274	998	1036	—	—	—
Mustard	210	21	120	3.55	—	—	—	747	74	426	—	—	—	—	—	—
Lentil	103	—	347	1.50	—	—	—	154	—	521	—	—	—	—	—	—
Gram	157	—	69	2.00	—	—	—	314	—	138	—	—	—	—	—	—
Kharif crops																
Paddy	3907	1444	1274	2.00	0.25	—	—	—	—	—	977	361	318	7815	2887	2547
Maize	—	—	456	3.00	—	0.15	—	—	—	1368	—	—	68	—	—	—
Arhar[d]	76	neg[e]	—	2.85	—	—	—	216	neg	—	—	—	—	—	—	—
Groundnut	64	—	—	1.40	—	—	0.45	90	—	—	29	—	—	—	—	—
Total								1520	74	2453	4279	1359	1423	7815	2887	2547

[a]Maulaganj.
[b]Arro.
[c]Bishnapur.
[d]It is a pulse crop.
[e]Negligible.

6.4 kg. The dung produced in Maulaganj and Arro is mainly used as fuel whereas in Bishnapur all the dung produced is used as manure in the field.

3.3.3. *Wood fuel.* No quantitative data were collected from which the forest resource potential for woody biomass and its surroundings (i.e. the area from which villagers gather fuelwood) could have been estimated. However, it was observed during the survey period that the western side of Bishnapur is entirely surrounded by dense forest cover. Analysis of the survey reveals that on an average one person per household has to walk 0.9 km spending nearly three and a half hours daily for collection of logs and twigs from nearby forests. In the other two villages there was no forest cover, so villagers mainly collected twigs from the roadside and fields.

The quantity of crop residue and dung available for use as fuel and the extent of use of crop residues as fodder is summarised in Table 6. It may be observed that the daily per capita crop residue available for use as fuel is maximum in Bishnapur (0.72 kg $capita^{-1}$) followed by Maulaganj and the minimum being in Arro (0.02 kg $capita^{-1}$). In the case of dung, highest per capita wet dung is available in Arro (6.52 kg $capita^{-1}$) which is followed by Maulaganj and Bishnapur. However, crop residues available for fodder are found to be at a maximum in Maulaganj (4.28 kg $animal^{-1}$), followed by Arro and the least in Bishnapur.

3.4. *Energy consumption pattern*

3.4.1. *Domestic sector.* Energy consumption in the domestic sector is mainly for three end-uses: cooking and water-heating (together), space heating and lighting.

Cooking and water heating, space heating. Table 8 presents the daily per capita energy consumption for cooking and water heating (together) in summer and winter months and space heating in winter months across the three villages according to different types of fuel. Using the energy conversion figures from Table 7, we have estimated in Table 8 daily per capita

Table 5. Daily production of dung by various animals

	Number of animals			Daily total production of wet dung (kg)		
Type of animal	M[a]	A[b]	B[c]	M	A	B
Bullock	203	151	200	1181	960	1098
Cow	71	85	282	340	467	918
Buffalo	—	69	133	—	562	1179
Total	274	305	615	1521	1989	3195

[a]Maulaganj.
[b]Arro.
[c]Bishnapur.

Table 6. Daily crop residue and wet dung produced in the three villages

	Maulaganj	Arro	Bishnapur
Crop residue as fuel (kg capita^{-1})	0.36	0.02	0.72
Crop residue as fodder (kg animal^{-1})	4.28	1.22	0.63
Wet dung (kg capita^{-1})	5.56	6.52	5.20

gross and useful* energy consumption for comparative analysis. The following observations can be made from Table 8:

—The consumption of energy is not uniform throughout the year. The per capita useful energy consumption for cooking and water heating in Maulaganj is 42% more in winter than in summer; in Bishnapur, it is 18% more and in Arro 19% more. In winter, a number of factors escalate energy requirements, such as higher food intake, more time needed to boil water due to low pressure and low temperature, increase in hot water requirements for bathing and washing clothes and utensils, a change in intake of food during winter, the need for space heating, etc.

—The per capita daily useful energy consumption for cooking and water heating (combined) in Maulaganj and Arro is below the minimum requirements estimated by the Advisory Board on Energy,[15] i.e. 2596 kJ day^{-1} of per capita useful energy in India (Maulaganj: 1967 kJ day^{-1} in summer and 2800 kJ day^{-1} in winter; Arro: 1667 kJ day^{-1} in summer and 1967 kJ day^{-1} in winter). On the other hand, in Bishnapur, the per capita useful energy consumption level is higher (2933 kJ day^{-1} in summer and 3500 kJ day^{-1} in winter). To understand the implications of lower consumption levels compared to the prescribed minimum requirements, it is important to note that the minimum requirements are arrived at based on LPG consumption in urban areas and the laboratory efficiency of LPG stoves. The actual operational efficiency of stoves may be lower. Also, due to differences in cooking habits and diets energy requirements for a balanced diet may differ across rural areas in different agro-climatic zones. Hence, it is difficult to say that there is scarcity of fuel in these villages since such urban and rural comparisons are very difficult.

—The fuel mix across the three villages in summer and winter months is shown in Table 8 indicating per capita daily gross energy mix for cooking and water heating (together) and space heating. Firewood is consumed most in Bishnapur and in the other two villages the share of firewood is nearly 50%. The remaining requirements are met by crop residues and dungcakes.

*"Useful" energy refers to the amount consumed net of conversion losses.[16]

Lighting. The requirement for lighting in the three villages is met by kerosene. Table 9 presents the average daily kerosene consumption in the three villages during summer and winter months. The daily consumption in all the three villages is greater than the all India average of 0.08 litre for the un-electrified households as estimated by the National Council of Applied Economic Research.[2]

Table 7. Conversion of physical units to calorific values and appliance efficiency

Energy source	Gross calorific value kJ g^{-1}	kJ cc^{-1}	kJ hr^{-1}	Appliance efficiency[d]
Biomass[a]				
Dungcake	8.92	—	—	0.08
Firewood: logs	19.89	—	—	0.14
Firewood: twigs	19.68	—	—	0.12
Crop residue	14.65	—	—	0.12
Petroleum products[b]				
Kerosene	27.84	34.37	—	0.42[e]
Diesel	30.88	37.37	—	—
Animate[c]				
Human	—	—	1960	—
Bullock pair	—	—	10,190	—

[a]See Ref. 12, and measured in oven dry weights.
[b]See Ref. 13.
[c]See Ref. 14.
[d]See Ref. 15.
[e]For cooking.

Table 8. Average daily per capita consumption for cooking and water heating (combined) and space heating

		Cooking and water heating								
		Summer			Winter			Space heating (winter)		
Fuel type	Unit	M[a]	A[b]	B[c]	M	A	B	M	A	B
Biomass										
Dungcake	kg capita^{-1}	0.62	1.29	0	0.63	1.34	0	0.10	0.02	0
Firewood										
Logs	kg capita^{-1}	0.03	0.12	0	0.02	0.14	0	0.002	0	0
Twigs	kg capita^{-1}	0.46	0.17	1.21	0.94	0.21	1.47	0.06	0.02	0.56
Crop-residue	kg capita^{-1}	0.19	0.04	0	0	0.09	0.01	0.47	0.10	0.09
Non-biomass										
Kerosene	lit capita^{-1}	0.001	0	0	0.001	0	0	0	0	0
Total[d]										
Gross	10^3 kJ capita^{-1}	18.13	17.87	23.87	24.57	20.10	29.03	9.20	2.10	12.43
Useful	10^3 kJ capita^{-1}	1.97	1.67	2.93	2.80	1.97	3.50	—	—	—

[a]Maulaganj.
[b]Arro.
[c]Bishnapur.
[d]Conversion factors from Table 7 are used.

The seasonal variation in consumption of kerosene is insignificant in all the three villages. There is a large variation in kerosene consumption between the three villages—minimum in Arro and maximum in Bishnapur. The reasons for this may be due to differences in (a) availability of kerosene, (b) family size, and (c) number of school-going children.

Energy share. Per capita daily energy consumption for cooking and water heating (summer and winter average), space heating (winter) and lighting (summer and winter average) are added up by combining Tables 8 and 9. Further, the percentage share of firewood, crop residue, dungcake and kerosene consumption in the three villages is worked out and presented in Fig. 1. The heavy dependence of biomass fuels—of the order of 98%—for meeting the domestic needs in these un-electrified villages is clearly indicated.

3.4.2. *Agricultural sector.* Only three types of energy sources go into the agricultural production system in the three villages, viz. human and animal power and diesel. For the present analysis, two major agricultural activities are studied, viz. land preparation and irrigation.

Table 10 shows consumption per hectare for crop production during the rabi and kharif seasons in the villages. It is seen that in Bishnapur a traditional method of agriculture (using

Table 9. Average daily household consumption of kerosene (l/household) for lighting

Village	Summer	Winter
Maulaganj	0.13	0.13
Arro	0.10	0.11
Bishnapur	0.14	0.14

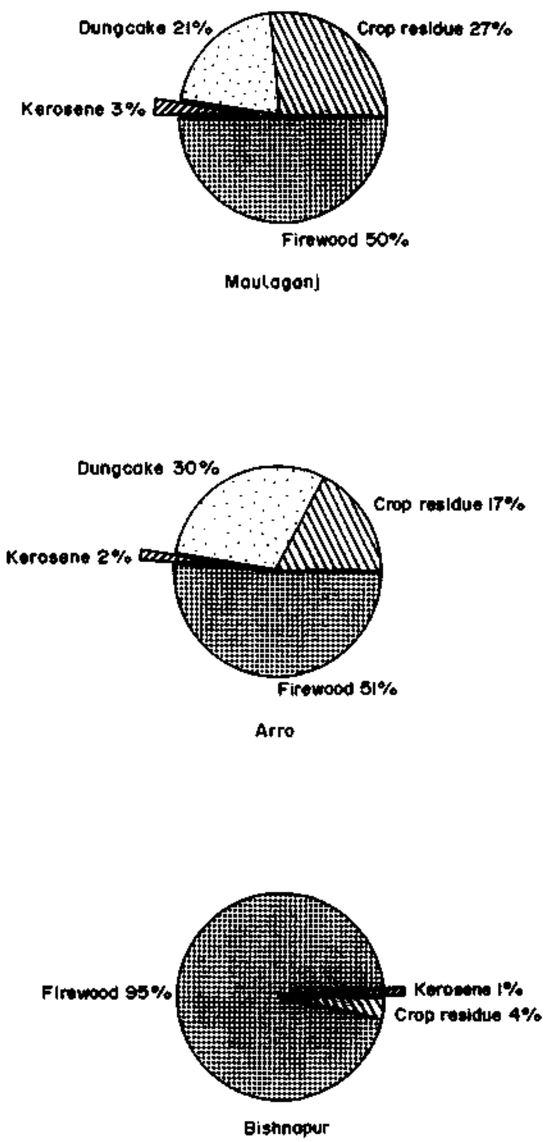

Fig. 1. Share of different fuels in domestic energy consumption.

Table 10. Energy consumption per hectare of total crop produced for various activities

Energy source	Rabi season						Kharif season					
	Land preparation			Irrigation			Land preparation			Irrigation		
	M[a]	A[b]	B[c]	M	A	B	M	A	B	M	A	B
Diesel (l)	15.12	25.95	0	1.75	12.85	0	16.51	12.82	0	10.38	19.77	0
Human (person days)	13.07	30.71	22.81	3.73	1.36	0	12.38	17.22	20.31	5.44	1.16	0
Animal (bullock pair days)	20.21	26.71	9.24	0	0	0	25.85	14.18	8.20	0	0	0
Total[d] (10^3 kJ ha^{-1})	3786	5338	1614	93	497	0	4707	2804	1438	435	745	0

[a]Maulaganj.
[b]Arro.
[c]Bishnapur.
[d]Conversion factors from Table 7 are used.

only human labour and animal power) is practised. This is reflected by the relatively lower value of crop yields in Bishnapur (Table 3).

Land preparation. It may also be observed from Table 10 that during the rabi season, the energy consumption per hectare for land preparation in Arro and Maulaganj is three and two times more than that in Bishnapur. The higher energy consumption in Maulaganj and Arro is partly due to the use of tractors for land preparation, in addition to human labour and animal power.

Irrigation. In Bishnapur no diesel is consumed for irrigation and instead crop production depends totally on natural rainfall. But it is observed that nearly five times more energy is consumed for lifting ground water for irrigation in Arro than in Maulaganj in both the cropping seasons (Table 10). Irrigation is more intensive in the kharif than in the rabi season in both the villages, mainly due to the paddy crop which is grown only in the kharif season.

Energy share. Figure 2 depicts the percentage share of different energy sources in the agricultural sector for land preparation and irrigation. It is seen that there is heavy dependence of animate power (human and animal), ranging from 70% in Arro to 100% in Bishnapur.

Surprisingly, in Arro, in spite of the highest amount of energy spent per hectare, the crop yields are still low. This suggests that the agricultural land in Arro may not be as productive as that of the other two villages.

3.5. *Gross energy in domestic and agriculture by end-use*

The disaggregated and total gross energy consumption for each village according to fuel type and end-use is presented in Table 11. The daily per capita gross energy consumption for cooking and water heating in Bishnapur is 24 and 39% higher as compared to Maulaganj and Arro, respectively. The higher consumption may be mainly due to relatively easy access to firewood from nearby forests for cooking and water heating (combined) in Bishnapur. Similarly, use of firewood for space heating in Bishnapur during winter is significantly higher as compared to the other villages. This may be due to easy access to a natural dense forest surrounding Bishnapur.

Table 11 also shows per capita daily consumption of total biomass for fuel purpose is at a maximum in Bishnapur (39×10^3 kJ day^{-1}),

Table 11. Source-activity matrix of gross energy consumption in the domestic and agricultural sector for the three villages

Energy sources and end-use	Domestic sector (day^{-1} $capita^{-1}$)					Agriculture sector		Total	
	Dungcake (kg)	Firewood (kg)	Crop residue (kg)	Kerosene (l)	Diesel (l)	Human (person days)	Animal (bullock pair days)	Domestic (10^3 kJ day^{-1})	Agriculture (10^3 kJ ha^{-1})
Maulaganj									
Cooking and water heating (summer and winter average)	0.63	0.73	0.10	0.001	—	—	—	21.35	—
Space heating (winter)	0.10	0.07	0.47	—	—	—	—	9.20	—
Lighting (summer and winter average)	—	—	—	0.02	—	—	—	0.76	—
Land preparation	—	—	—	—	15.82	12.73	23.03	—	4247
Irrigation	—	—	—	—	6.07	4.59	—	—	264
Total for Maulaganj	0.73	0.80	0.57	0.02	21.89	17.32	23.03	31.31	4511
Arro									
Cooking and water heating (summer and winter average)	1.31	0.32	0.06	—	—	—	—	18.98	—
Space heating (winter)	0.02	0.02	0.10	—	—	—	—	2.10	—
Lighting (summer and winter average)	—	—	—	0.02	—	—	—	0.52	—
Land preparation	—	—	—	—	19.39	23.97	20.45	—	4071
Irrigation	—	—	—	—	16.31	1.26	—	—	621
Total for Arro	1.33	0.34	0.16	0.02	35.70	25.23	20.45	21.60	4692
Bishnapur									
Cooking and water heating (summer and winter average)	—	1.34	0.003	—	—	—	—	26.45	—
Space heating (winter)	—	0.56	0.09	—	—	—	—	12.43	—
Lighting (summer and winter average)	—	—	—	0.01	—	—	—	0.48	—
Land preparation	—	—	—	—	—	21.56	8.72	—	1526
Irrigation	—	—	—	—	—	—	—	—	—
Total for Bishnapur	—	1.90	0.09	0.01	—	21.56	8.72	39.36	1526

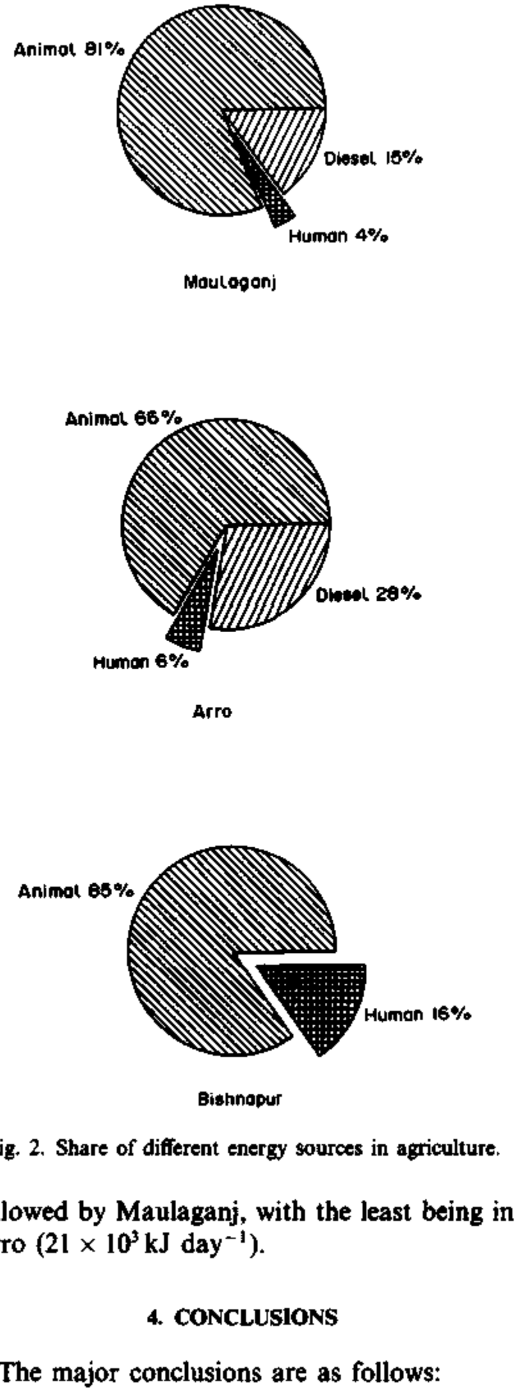

Fig. 2. Share of different energy sources in agriculture.

followed by Maulaganj, with the least being in Arro (21×10^3 kJ day^{-1}).

4. CONCLUSIONS

The major conclusions are as follows:

—Where firewood is available, this is preferred to other fuels for cooking, water heating and space heating as is observed in Bishnapur, which is surrounded by a natural dense forest. Also, easy availability of firewood resources appears to lead to excessive energy consumption.

—18 to 42% additional (useful) energy is consumed in winter.

—There is heavy dependence (98%) on biomass fuels for meeting domestic end-uses and on animate power in agriculture.

—Higher levels of mechanization significantly improve crop yield if the productivity of the land is high.

Acknowledgements—The authors are grateful to Dr. R. K. Pachauri, Director, TERI, for initiating this project which was supported by the Uttar Pradesh State Electricity Board, Lucknow, India. The co-operation of different government officials of Uttar Pradesh is acknowledged. The authors would like to extend their warmest appreciation to the late Dr. S. C. Agrawal, Research and Action Division, State Planning Institute, Lucknow, Uttar Pradesh for his involvement in the project. The authors are also indebted to the field investigators, Mr. Mohammed Tayub and Mr. Alok Saigal, for helping us with the survey. The co-operation and assistance provided by the villagers of Maulaganj, Arro and Bishnapur is gratefully acknowledged.

REFERENCES

1. R. K. Bose, Biomass energy resource assessment through rural energy surveys—A common approach, *Commonwealth Science Council Technical Publication Series No. 188*, (C. Y. Wereko-Brobby, Ed.), pp. 85–123. Commonwealth Science Council, London (1985).
2. National Council of Applied Economic Research (NCAER), *Domestic Fuel Survey with Special Reference to Kerosene—Volume I and II.* New Delhi (1985).
3. R. K. Pachuari, R. K. Bose and C. Gadhok, Report on methodology for conducting rural energy surveys—A literature review and design of questionnaire, *Tata Energy Research Institute (TERI) Discussion Paper No. 05-83.* TERI, New Delhi (December, 1983).
4. R. K. Bose, Renewable energy potential and its consumption in village Berka Alimuddin of Haryana, *Tata Energy Research Institute Discussion Paper No. 05/87.* TERI, New Delhi (November, 1987).
5. R. K. Bose, C. Puri and V. Joshi, A plan for renewable energy development in a village of Uttar Pradesh: Village—Maulaganj in Gorakhpur district. Report prepared by the Tata Energy Research Institute, New Delhi (September, 1987).
6. C. Puri, R. K. Bose and V. Joshi, A plan for renewable energy development in a village of Uttar Pradesh: Village—Arro in Pratapgarh district. Report prepared by the Tata Energy Research Institute, New Delhi (September, 1987).
7. V. Joshi, R. K. Bose, C. Puri and T. K. Bhattacharya, Renewable energy potential and its development in a tribal village of Uttar Pradesh: Village—Bishnapur in Bahraich district. Report prepared by the Tata Energy Research Institute, New Delhi (August, 1987).
8. C. Puri, Analysis of energy consumption and production pattern in Dhanawas: A survey report, *Tata Energy Research Institute Discussion Paper No. 02/88.* TERI, New Delhi (June, 1988).
9. Tata Energy Research Institute and Department of Non-conventional Energy Sources, *Application of the Rural Energy Model in Energy Planning—Part B (Analysis of 20 villages survey data).* TERI, New Delhi (September, 1989).
10. R. C. Maheshwari, *et al. Energy Census and Resources Assessment of Village Islamnagar in the District of Bhopal*, p. 35. Central Institute of Agricultural Engineering, Bhopal, India (October, 1981).
11. Fertilizer Association of India. *Fertilizer Statistics 1986–87*, p. II–34. New Delhi (1987).

12. National Council of Applied Economic Research (NCAER), *Rural Energy Consumption in Northern India*. New Delhi (1981).
13. Ministry of Petroleum and Natural Gas, *Indian Petroleum and Natural Gas Statistics 1986–87*, see Appendix. Economics and Statistics Division, Government of India, New Delhi (October, 1987).
14. Indian Council of Agricultural Research (ICAR), *Research Digest on Energy Requirements in Agricultural Sector (1971–82)*, p. 159. Punjab Agricultural University, Ludhiana (1985).
15. Advisory Board on Energy, *Towards a Perspective on Energy Demand and Supply in India in 2004/05*. Government of India, New Delhi (1985).
16. J. Sathaye and S. Meyers, Energy use in cities of the developing countries. *Annu. Rev. Energy* **10**, 117 (1985).