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Energetics in paddy cultivation in Uttara Kannada district

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Abstract

Agriculture requires three major resources, land, water and energy. Land, being a fixed resource, agricultural productivity could be linked directly to the availability of water (rain or irrigation) and energy inputs. Land preparation, irrigation, harvesting, threshing and transportation are the main tasks dependent on mechanical energy apart from manure input, seed etc. Since rainfed paddy is the major crop, agriculture in Uttara Kannada is less dependent on irrigation. However, there is scope to grow a second crop through irrigation. Water and the associated average daily energy requirements depend on the area irrigated, type of crop, sources of water, total period of irrigation and irrigation efficiency. Farm Yard Manure (FYM) is a major component of the input energy in paddy cultivation. However, the level of input changes from zone to zone (hilly, interior and coastal) and across various landholdings. The energetics in rainfed paddy cultivation is discussed in this paper. Detailed analyses of energy input in various categories of farmers, based on stratified random sampling, show that marginal farmers get higher yield compared to others. The energy input in this category in the form of FYM is almost double to that applied by large farmers (>2 ha). This greater usage of FYM by marginal farmers is attributed to higher dung availability (livestock per hectare in the marginal farmers category is almost twice that of medium farmers or four times that of large farmers). © 2000 Elsevier Science Ltd. All rights reserved.

Keywords: Agriculture; Paddy; Energy inputs; Energetics; Farm yard manure; Irrigation; Productivity

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1. Introduction

The agriculture sector represents both consumers and producers of various forms of energy. Valuable byproducts of agriculture, like crop residues, are used as animal feed, cooking fuel and as raw material in industries. Animals provide draught power and their residues in turn, are used as manure and fuel. The level and pattern of energy use in agriculture, as well as its contribution to energy supplies, depends on a variety of agronomic and socio-economic factors. In India, agriculture not only provides food for all, but also employment to 70% of the population, generates 40% of the national income and consumes about 10% of the commercial forms of energy.

Crop cultivation requires application of both animate (bullock, human power) and inanimate (tractors, tillers etc.) forms of energy at different stages. Nutrients are provided through Farm Yard Manure (FYM), chemical fertiliser or both. Pesticides are required to check or prevent pest attack. Irrigation is done either manually (manually and animal operated) or through diesel/electric pumpsets (to lift ground water). Besides this, energy is required for processing the output and transporting it to consumer centers.

Available data compiled by government machineries is inadequate to show a detailed energy consumption pattern in agriculture. Aggregate information of human labourers and number of pumpsets conceals the wide disparity in regional energy consumption. Also, these aggregates exclude energy input into fertiliser production. This required a detailed survey to get information on various inputs, their quantity and time of application.

Energy analyses in agriculture include computation of the energy content in inputs that go into crop production and comparison of the same with the energy content in the output. For instance, energy input includes energy content of seeds, irrigation, human and animal power etc. Studies indicate that the output/input ratio under Indian conditions is in the range 1.5–2.7 [1].

During field research in Kumta taluk, farmers expressed that yields have been declining, and higher fertiliser application was needed every year to maintain yield. This was true with at least 60% of the farmers who have switched to inorganic fertilisers. Analyses of data on yield show that despite rising input levels, yields have been declining or were stagnant in the last decade. Yield declines are strongly associated with the duration that intensive production has been practiced in each taluk. Similar trends have been reported in other regions where intensive agriculture has been practiced. This indicates that land degradation is the main factor in reducing productivity.

An earlier study of Karnataka's agricultural sector [2] revealed a stagnant food production for the last 15 years in spite of the increases in irrigation facility, pesticide and fertiliser input. This implies that investments made in this sector, during the sixth and seventh plan periods, have not yielded any net benefit through an increase in per capita yields, either to the farmers or to the economy.

There has been rising concern over intensive agriculture through chemical fertilisers, as it may not be sustainable and might damage the environment or other productive sectors, such as fisheries (through water pollution) etc. Decisive conclusions here are possible only after detailed studies relating to various energy inputs and corresponding yields at the village and taluk levels are undertaken. In view of this, detailed investigations were conducted in 90 villages of Kumta taluk to identify the factors responsible for variation in yield.

2. Objectives

The objectives of the study are to

1. measure the quantity of energy inputs in paddy cultivation,
2. find out its type and share in productivity,
3. analyse the regional variation in the amount and type of energy used,
4. examine the relationship between landholding and energy consumption, and
5. identify factors responsible for difference in levels of energy consumption.

2.1. Study area

The Uttara Kannada district in the mid-western part of Karnataka state (Fig. 1) is selected for this study. It lies 74°9′ to 75°10′ east longitude and 13°55′ to 15°31′ north latitude, extending over an area of 10,291 km^2, 5.37% of the total area of the state with a population above 1.2 million. It is a region of gentle undulating hills, rising steeply from a narrow coastal strip bordering the Arabian sea to a plateau at an altitude of 500 m with occasional hills rising above 600–860 m.

This district, with 11 taluks, can be broadly categorised into three distinct regions — coastal lands (Karwar, Ankola, Kumta, Honnavar and Bhatkal taluks), mostly forested Sahyadrian interior (Supa, Yellapur, Sirsi and Siddapur taluks) and the eastern margin where the table land begins (Haliyal, Yellapur and Mundgod taluks). Climatic conditions range from arid to humid due to physiographic conditions ranging from plains, mountains to coast.

3. Materials and methods

Secondary data on production, yield and area was collected from the agriculture department and from annual reports from the office of Principal Agricultural Officer, Karwar.

3.1. Household energy consumption for agricultural activities

A detailed survey was conducted in 90 villages spread over the coast, interior and hilly zones of Kumta taluk, covering all categories of landholdings. A questionnaire on power sources, such as human, animal, prime movers and machinery in various farm operations and organic (FYM) and inorganic (fertilisers, pesticides etc.) inputs etc. was used to collect data from 1304 households, by stratified random sampling, during 18 months of field research. Out of these, 1068 households contained complete information on agriculture, which was analysed to

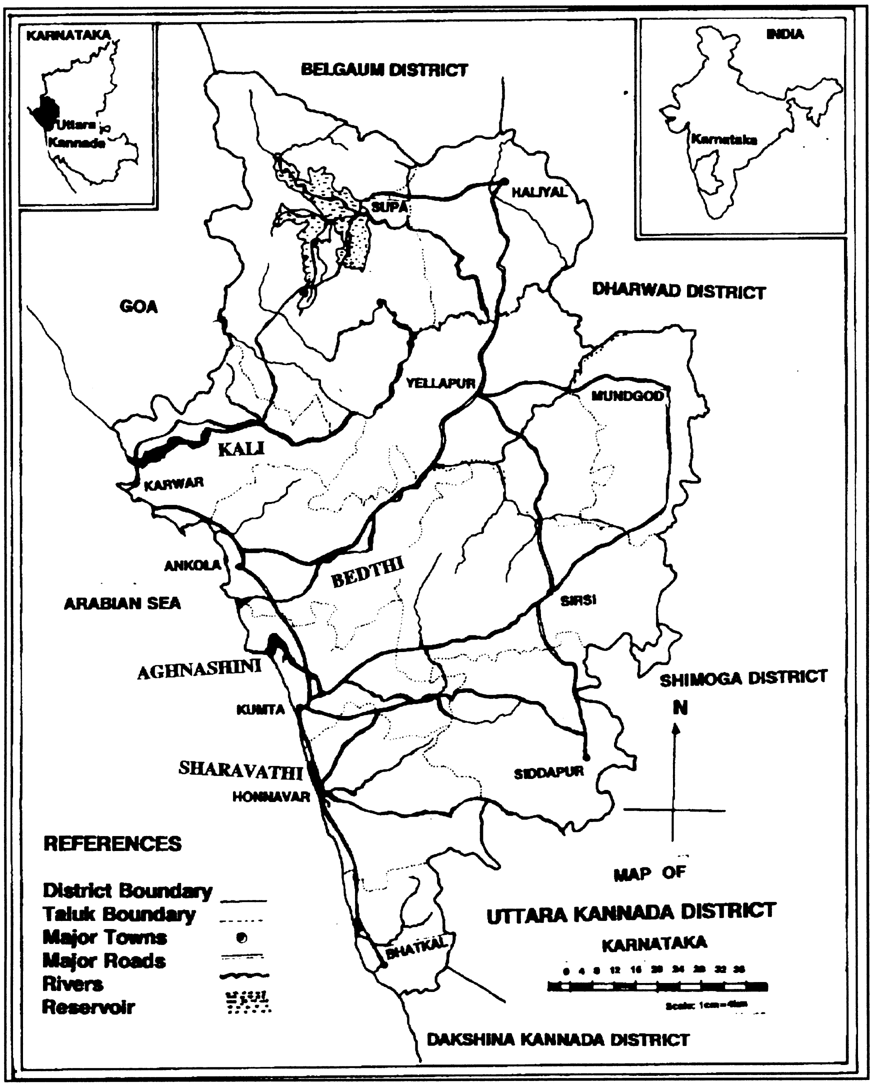

Fig. 1. Map of Uttara Kannada district.

calculate the operationwise and sourcewise energy consumption (regionwise and based on landholding) on a unit area basis.

4. Collection of data

The questionnaire data was collected periodically by a combination of recall and actual measurements (in a few farms — at least one from each category in each village).

Operationwise energy flow patterns were studied to find energy consumption. The energy

Table 1

Item	Unit	Energy equivalent (GJ/unit)
Human hour	h	0.0010442
Draught animal	h	0.019168
Farm yard manure	kg	0.047990
Paddy straw	kg	0.013300
Paddy husk	kg	0.014170
Rice	kg	0.015195
DAP fertiliser	kg	0.065800
Complex	kg	0.030340
Urea	kg	0.079500
Pesticide	kg	0.101325

data pertaining to ploughing, sowing, transplantation/broadcasting, irrigation, weeding, harvesting and threshing were obtained from sample households. Since the pesticide's proportion to total energy is insignificant, it has not been included in the energy computation. These values are converted to common energy units — Giga Joules (GJ). The energy conversion figures have been obtained from various literatures [3–6] as listed in Table 1.

5. Literature review

Tivy [7] discusses the reciprocal interactions between agricultural or agriculturally associated organisms and their physical habitat. This study illustrates varying intensities of rice production, in terms of type and amount of direct and indirect energy subsidies, in Japan, Borneo and California. In Borneo, methods of cultivation are simple and yield is dependent on the inherent fertility of the soil. Rice yield is about 7,318,080 kcal/ha, and energy efficiency is of the order of 7.08%. In Japan, rice cultivation is more labour intensive as a higher proportion of the direct energy subsidy is accounted for by mechanisation, and indirect subsidies are twice that of direct subsidy. Rice yield is 17,598,240 kcal/ha, and energy efficiency is 2.45%. The level of inputs is highest in California with 22,360,800 kcal/ha yield and energy efficiency of 1.55%. This study shows that energy output is a function of the intensity of agriculture. There is an inverse relationship between energy efficiency and productivity.

Pimentel et al. [8] analysed the changes in US maize production over a quarter century and showed that yields have increased by 138%, achieved at the cost of a 310% increase in fossil fuel consumption, while the energy ratio decreased from 3.72 to 2.8. The energy ratio, first applied by Black [9], is the ratio of the calorific value of food to the energy required to produce it.

Pimentel and Pimentel [10] provide comparative analyses in energy input for rice production. Energy inputs for a hectare of rice total 1.0×10^6 kcal, with about two-third expended for manpower and the balance for seeds. The yield in Borneo is about 2 ton/ha or about 7.3×10^6 kcal food energy. The output/input ratio is 7:1, denoting a relatively high return for the investment. USA uses high energy inputs (14.4×10^6 kcal), particularly fossil fuel. The average yield per hectare is 6.16 ton (22.4×10^6 kcal). The energy output/input ratio is 1.6:1. Rice production in Japan is still labour intensive, requiring about 1730 h (8.03×10^6 kcal) of manpower per hectare. The average yield per hectare is about 4.8 ton (17.6×10^6 kcal) resulting in an output/input ratio of 2.45:1, compared to USA's 1.6:1, reflecting more efficiency in production.

Rijal et al. [11] examined the total energy requirements and outputs of subsistence agriculture in rural Nepal with special emphasis on animate energy inputs. They analyse the availability of animate energy, usage pattern and various issues of energy demand at micro levels and their impact at macro level. The output/input ratio computed for maize, paddy and wheat is relatively higher here (2.4–7.5) compared to the highly mechanised agriculture of developed countries (1.5–3.5). They conclude that the energy output/input ratio declines as the level of mechanisation increases.

Mathew et al. [12] analysed energy flow patterns in rainfed paddy cultivation under three puddling treatments — bullock drawn plough, power tiller and tractor. Their study reveals that: (a) energy consumption per hectare for treatment with bullocks, tractor and tiller was 14.2, 14.2 and 15.0 GJ, respectively; (b) output/input ratio for tractor, bullock and tiller treatment was 7.63, 6.58 and 5.4, respectively; (c) fertilisers and chemicals constitute a major portion of total energy input and; (d) the share of human power is maximum in planting and harvesting operations.

Bonetto and Carcano [13] compared rice productivity in three kinds of treatment — control without fertiliser application, fertiliser application with urea (applied in two split dressings equivalent to 20 kg/ha each) and application of *Azolla caroliniana* (incorporated at planting at a rate equivalent to 5 ton dry weight per ha) — and concluded, based on the grain yields of 7.3:7.8:8.5 ton/ha, that Azolla treated yield is significantly greater than the other two.

6. Results and discussion

6.1. Land utilisation in Uttara Kannada district

The forest and cropped areas at the end of 1993–1994 were about 80.96% (8296 km^2) and 10.94% (1121 km^2), respectively.

6.2. Crops in Uttara Kannada district

The paddy is the major crop in all taluks of the district which records a marginal increase in the area under paddy (3.15%) for the last 20 years. Haliyal (168.54 km^2) and Mundgod (136.34 km^2) taluks in the plains lead in the area under paddy.

6.3. Production of various crops

The introduction of high yielding varieties (HYV) of paddy in the early 1970s increased production from 2.26 (in 1973–1974) to 3.03 million ton (in 1980–1981). In spite of a 3.15% increase in total cultivated area, production declined by the mid 1980s, coming down to 1.75

million ton (in 1992–1993). The yield declined from 3.3 to 1.9 ton/ha despite the continued use of HYV, greater application of inorganic fertilisers (26.66% increase) and use of pesticides. The HYV yield changed from 2.5 to 2.2, while the improved variety changed from 3.7 to 1.6 ton/ha. This fluctuation in production and yield along with area, rainfall and fertiliser (inorganic) is depicted in Fig. 2. Commonly cited reasons for the decline are untimely or failure of rain, pests and decline in organic inputs.

Fig. 3 shows Haliyal (18.76%) and Siddapur (4.56%) with the highest and lowest percentage area under crops among the 11 taluks.

Talukwise rainfall data (in mm) of the last 20 years shows that coastal taluks — Bhatkal (3994), Honnavar (3637), Ankola (3543), Kumta (3377) and Karwar (3214) — get higher rainfall compared to hilly taluks — Siddapur (2982), Supa (2534), Yellapur (2438) and Sirsi (2379) — or plain taluks — Mundgod (1203) and Haliyal (1179).

In order to see the effect of inorganic fertiliser input on yield over a period, regression analyses (both linear and nonlinear) were performed with 13 years data (Paddy Yield kg/ha, fertiliser ton). The relationship is found to be linear of the form

$$\text{Yield (kg/hectare)} = 3465 - 2.92(\text{fertiliser tonnes}), \quad \text{with } R = \text{correlation coefficient} = 0.79.$$

This shows that yield declined at the rate of 2.92 with every additional fertiliser input, which may be due to excess or blind usage of fertiliser (based on advertisement in mass media) without considering soil condition (saline or otherwise) and its nutrient contents.

Most of the households practice rainfed paddy cultivation while only, a few use irrigation

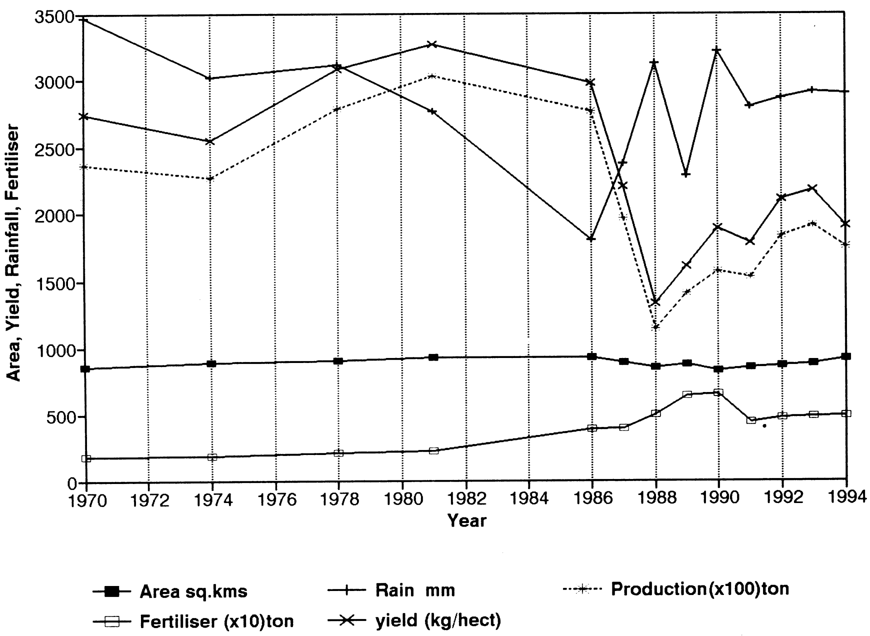

Fig. 2. Area, production, yield — Paddy. Temporal changes in Uttara Kannada.

(for the second crop, March–April). In the sample of 1068 households in the Kumta taluk, 12 grow two crops in a year.

In order to see the effect of annual changes in rainfall and fertiliser input on yield, we have performed multiple regression of the variables: cultivated area (ha), annual rainfall (mm), inorganic fertiliser (ton) and yield (kg/ha). The probable relationships are

$$\text{Yield} = -9401.17 + 0.132\ (\text{area}), \quad \text{with } R = 0.66.$$

$$\text{Yield} = -13753.3 + 0.1665\ (\text{area}) + 0.4615\ (\text{rain}), \quad \text{with } R = 0.72.$$

$$\text{Yield} = -2039.2 + 0.0632\ (\text{area}) - 0.09\ (\text{rain})\ - 0.2448\ (\text{fertiliser}), \quad \text{with } R = 0.86.$$

Most of the farming systems here use a high quantity of organic manure. The torrential south-west monsoon depletes the soil of nutrients due to rapid soil erosion. This requires large quantities of leaf and organic manure. The leaf manure helps in providing soil cover and, hence, moisture in the soil. Decay of these materials enriches the soil with nutrients. In the hilly taluks, due to reasonably good forest cover and dung availability (at present), substantial quantities of FYM and green manure are available. While in the coastal taluks, dense human population and less forest cover deprive the soil of the required nutrients.

The stagnation and declining yield in the late 1980 imply that investments made through fertilisers, irrigation and related areas have not yielded a net benefit, either to farmers or the economy, through increase in per capita yields. In view of this, to get insight into the energy

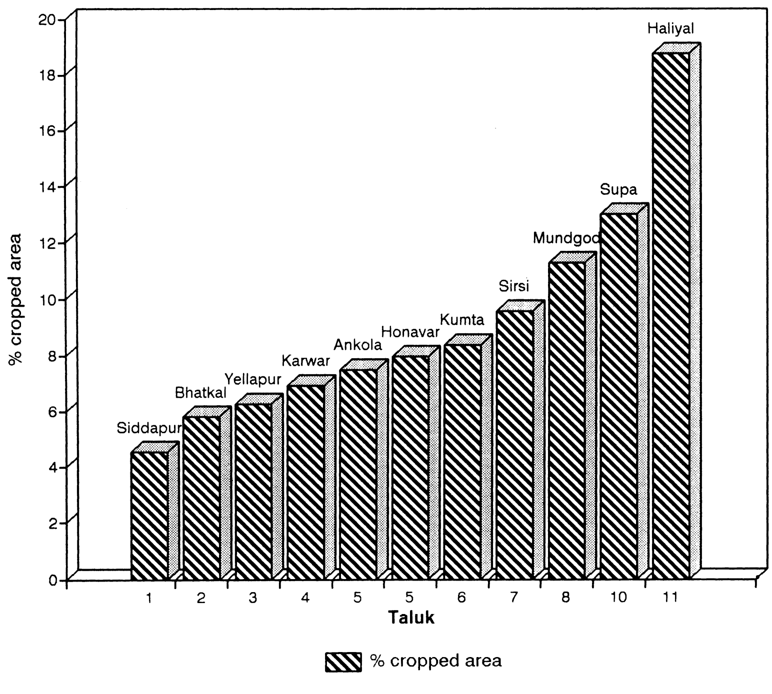

Fig. 3. Talukwise percentage cropped area.

requirements in agriculture and factors contributing to variation in yield, a detailed survey of 1304 households spread over 90 villages covering hilly, interior and coastal zones of Kumta taluk was undertaken. Out of these, reliable data on paddy cultivation was obtained from 1068 households. It is seen that population density varies from 0.35 (hilly), 1.35 (interior) to 5.31 (coastal) persons/hectare and forest cover changes from 25% (coastal), 76% (interior) to 89% (hilly). Livestock density varies from 0.24 (hilly), 0.70 (interior) to 1.63 (coastal) animals/ha. There is a positive linear correlation between livestock and human density. Human and animal pressures on forests for fuel, fodder and green manure have resulted in declining forest cover in the coast.

Table 2
Energy requirements (GJ/ha) for various operations in paddy cultivation — coastal zone

Operation	Category (ha)	(0–0.4)	(0.4–0.8)	(0.8–1.2)	(1.2–1.6)	(1.6–2)	(> 2)	All categories	
	En input	Average	Average	Average	Average	Average	Average	Average	SD
	N[a]	248	112	40	23	12	25	460	
	Land (ha)	0.31	0.66	1.09	1.53	1.94	3.01	0.69	0.69
Tilling	BH[b]	1.57	3.81	5.46	9.07	10.03	9.25	3.45	3.55
	HH[c]	0.13	0.28	0.34	0.57	0.55	0.63	0.24	0.32
Sowing	S[d]	0.97	1.52	2.51	3.62	3.97	4.01	1.58	1.20
	BH	0.36	0.55	1.04	1.17	1.20	1.01	0.56	0.79
	HH	0.02	0.03	0.06	0.07	0.07	0.06	0.03	0.04
Irrigation	HH	0.04	0.09	0.12	0.09	0.13	0.11	0.07	0.06
	BH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Weeding	HH	0.06	0.10	0.12	0.11	0.16	0.13	0.09	0.05
Transplant	BH	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
	HH	0.13	0.30	0.61	0.89	1.51	2.89	0.40	0.89
Manure	FYM[e]	6.15	14.95	24.26	19.68	16.47	31.62	13.59	20.90
Fertiliser	DAP	0.03	0.05	0.00	0.00	0.00	0.00	0.03	0.47
	Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harvest	HH	0.14	0.25	0.40	0.77	0.91	1.63	0.30	0.41
	BH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Threshing	HH	0.07	0.14	0.26	0.25	0.42	0.48	0.14	0.14
	BH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Input	Total GJ	10.45	23.73	37.88	40.08	40.21	59.27	22.20	22.51
Output	GJ	17.81	29.01	43.72	45.57	77.37	114.61	30.85	29.21
Input/ha	GJ/ha	33.22	35.94	34.65	26.14	20.70	19.72	32.14	
Output/ha	GJ/ha	56.62	43.94	39.99	29.72	39.83	38.14	44.65	
O/I	Output/Input	1.70	1.22	1.15	1.13	1.92	1.93	1.39	1.30

[a] *N* — no. of samples.
[b] BH — Bullock hour.
[c] HH — Human hour.
[d] S — Seed.
[e] FYM — Farm yard manure.

6.4. Energy use pattern in agriculture

Tables 2–4 list operationwise (tilling, threshing, etc.) The energy requirements for various landholdings in the coastal, hilly and interior zones, respectively.

In the coast, the total energy input in GJ per hectare varies from 33.22 (< 0.4 ha), 34.65 (0.8–1.2 ha), 26.14 (1.2–1.6 ha) to 19.72 (> 2 ha). The output in GJ per hectare also varies from 56.62 (< 0.4 ha), 39.99 (0.8–1.2 ha) to 38.14 (> 2 ha). The output–input ratio varies from 1.13 (1.2–1.6 ha) to 1.93 (> 2 ha).

Similar trends are noticed in interior and hilly zones. In the hilly zone the input energy varies from 55.95 (< 0.4 ha) to 17.50 (> 2 ha) and the corresponding output varies from 58.36

Table 3
Energy requirements (GJ/ha) for various operations in paddy cultivation — hilly zone

Operation	Category (ha)	(0–0.4)	(0.4–0.8)	(0.8–1.2)	(1.2–1.6)	(1.6–2)	(> 2)	All categories	
	(En input)	Average	Average	Average	Average	Average	Average	Average	SD
	N[a]	160	101	30	29	8	13	341	
	Land (ha)	0.30	0.73	1.17	1.56	2.01	3.55	1.01	1.09
Tilling	BH[b]	1.89	4.56	7.41	9.39	11.00	8.36	4.92	4.39
	HH[c]	0.10	0.26	0.40	0.49	0.60	0.46	0.27	0.24
Sowing	S[d]	1.23	1.99	2.96	2.73	4.68	3.04	2.10	1.53
	BH	0.18	0.43	0.65	0.79	1.01	1.02	0.47	0.46
	HH	0.02	0.03	0.05	0.05	0.05	0.08	0.03	0.04
Irragation	HH	0.04	0.08	0.13	0.11	0.25	0.11	0.09	0.15
	BH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wedding	HH	0.06	0.10	0.13	0.13	0.19	0.15	0.10	0.10
Transplant	BH	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
	HH	0.32	0.54	0.92	0.98	1.62	3.56	0.87	1.46
Manure	FYM[e]	11.87	16.46	13.99	22.05	31.14	34.31	21.11	14.83
Fertiliser	DAP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harvest	HH	0.11	0.27	0.48	0.39	0.86	1.71	0.40	0.57
	BH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Threshing	HH	0.06	0.13	0.18	0.18	0.29	0.52	0.15	0.17
	BH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total/Input	Total GJ	16.62	26.64	30.21	41.16	56.66	62.09	33.10	12.19
Output	GJ	17.33	33.01	48.00	49.08	67.00	108.70	38.40	35.53
Input/ha	GJ/ha	55.95	36.55	25.72	26.37	28.20	17.50	32.90	
Output/ha	GJ/ha	58.36	45.29	40.87	31.44	33.35	30.64	38.17	
O/I	Output/input	1.04	1.24	1.59	1.19	1.18	1.75	1.16	2.91

[a] N — No. of samples.
[b] BH — Bullock hour.
[c] HH — Human hour.
[d] S — Seed.
[e] FYM — Farm yard manure.

to 30.64. In the interior zone the input energy varies from 29.18 (< 0.4 ha) to 19.82 (> 2 ha) while, output varies from 32.87 (0.4 ha) to 28.08 (> 2 ha).

It is evident from these tables that paddy cultivation mainly depends on organic manure (FYM), which constitutes 70–74% of total input. Yield in the three zones is dependent on the inherent fertility of soil and successful maintenance of the nutrient cycle. The productivity in all zones is dependent on the level of inputs, which is the intensity of agriculture as organic inputs etc. As the field sizes are small and fragmented, there are problems in cultivating with the help of tractors, tillers etc. The design of machineries to substitute for manual tasks under such conditions is complex and expensive, which makes mechanisation of agriculture inappropriate.

It is to be noted that the new inputs typical of many phases of development in paddy

Table 4
Energy requirements (GJ/ha) for various operations in paddy cultivation — interior zone

Operation	Category (ha)	(0–0.4)	(0.4–08)	(0.8–1.2)	(1.2–1.6)	(1.6–2)	(> 2)	All zones	
	(En input)	Average	Average	Average	Average	Average	Average	Average	SD
	N[a]	90	100	27	23	13	14	267	
	Land (ha)	0.38	0.54	1.10	1.55	1.95	3.45	0.69	0.68
Tilling	BH[b]	2.30	1.38	5.03	6.27	9.58	9.61	2.79	3.09
	HH[c]	1.20	1.33	0.70	0.87	0.67	0.67	0.44	1.40
Sowing	S[d]	1.41	0.82	2.63	2.75	4.23	4.10	1.63	1.42
	BH	0.22	0.19	0.43	0.43	1.07	0.62	0.20	0.33
	HH	0.02	0.01	0.05	0.05	0.06	0.10	0.03	0.03
Irrigation	HH	0.05	0.05	0.08	0.08	0.10	0.06	0.06	0.05
	BH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Weeding	HH	0.06	0.06	0.10	0.10	0.23	0.19	0.08	0.07
Transplant	BH	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
	HH	0.42	0.33	0.52	0.90	1.20	3.73	0.41	0.95
Manure	FYM[e]	12.78	45.52	29.82	30.45	36.12	38.35	16.20	10.12
Fertiliser	DAP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harvest	HH	0.15	0.14	0.36	0.63	1.00	1.32	0.28	0.34
	BH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Threshing	HH	0.09	0.07	0.19	0.22	0.38	0.55	0.12	0.15
	BH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total/input	Total GJ	11.09	10.16	42.53	46.55	59.65	68.37	24.94	19.83
Output	GJ	12.49	8.81	56.50	78.60	82.98	96.86	34.42	40.11
Input/ha	GJ/ha	29.18	18.81	38.62	30.04	30.59	19.82	36.36	29.00
Output/ha	GJ/ha	32.87	16.32	51.31	50.73	42.55	28.08	50.17	58.66
O/I	Output/input	1.13	0.87	1.32	1.69	1.39	1.41	1.38	2.02

[a] N — No. of samples.
[b] BH — Bullock hour.
[c] HH — Human hour.
[d] S — Seed.
[e] FYM — Farm yard manure.

cultivation are divisible. New seeds and fertiliser can be bought in any quantity, according to farmers' inclination and financial position. However, indiscriminate usage of fertiliser has resulted in significant reduction in yield over a period of time. Some farmers who switched to inorganic fertiliser in the early eighties, have returned to organic farming due to declining yield and water pollution problems. Because of the large gap between the average farmer's yield and maximum attainable yield, total fertiliser use during 1993–1994 came down in the Kumta, Ankola, Honnavar, Karwar and Siddapur taluks. Organisational improvements and careful operation make important contributions to raise output. Tables 2–4 demonstrate that skilled and experienced small farmers are in just as good a position as large farmers to raise the productivity of the land.

6.5. Regionwise variation in energy consumption pattern in agriculture

Table 5 lists regionwise energy consumption (GJ/ha) in paddy cultivation. The energy input from all sources (such as FYM etc.) is in the range 35.47 (interior), 37.24 (coastal) to 43.21 (hilly), the major component being organic (FYM). The hilly zone with 89.78% forest cover and dung yield (kgs/animal/day) of 5.8 ± 1.8 is rich in organic matter compared to the coast (forest cover 27.66%, dung yield 3.26) and interior (forest cover 78.14%, dung yield 3.94). The average paddy yield is about 1.73 ton/ha. Regionwise variation shown in Fig. 4 depicts output more or less the same in all zones, while input energy is higher in the hilly zone.

In order to assess the effect of landholding on energy input, the data is categorised based on landholding. Table 6 shows that marginal farmers (<0.4 ha) get the maximum yield of 2.1 ton/ha compared to other categories. Fig. 5 shows marginal farmers with the maximum input of 46.09 compared to 23.46 GJ/ha (>2 ha category). This significant variation in energy input and yield across zones and landholdings necessitated detailed analyses to see changes in energy

Table 5
Regionwise variations in different energy inputs and outputs (GJ) for paddy cultivation

Zone	N[a]		BH[b]	HH[c]	S[d]	FYM[e]	Fert[f]	Total input	Total output	Paddy out/in	Paddy yield (0.1 ton)
All	1068	Average	6.62	1.46	3.05	27.42	0.03	38.57	50.36	1.31	17.89
		SD	4.51	1.68	2.59	98.07	0.68	39.91	27.40	2.31	9.76
Coastal	460	Average	6.56	1.46	2.98	26.20	0.04	37.24	51.76	1.39	18.40
		SD	4.38	1.35	2.32	89.07	0.82	36.12	30.10	0.34	10.70
Hilly	341	Average	6.61	1.43	3.16	32.01	0.00	43.21	50.14	1.16	17.83
		SD	4.83	0.99	2.59	119.07	0.00	36.12	29.11	0.24	10.35
Interior	267	Average	6.72	1.51	3.02	24.18	0.05	35.47	49.05	1.38	17.40
		SD	4.31	2.43	2.88	82.28	0.85	33.43	21.30	0.26	7.63

[a] N — No. of samples.
[b] BH — Bullock hour.
[c] HH — Human hour.
[d] S — Seed.
[e] FYM — Farm yard manure.
[f] Fert — Fertiliser.

consumption within a zone across various landholdings. Table 7 lists categorywise and zonewise the energy consumption patterns. In all landholding categories (except 1.2–1.6 ha) energy input is higher in the hilly zone. Energy intensive agriculture is practiced by marginal and small farmers (0.4–0.8 ha) due to higher availability of organic matter (in the form of dung as livestock in these categories range from 6.9 to 7.9 per ha). Similarly, the energy output per hectare is higher in these categories. It appears the marginal and small farmers have better output per hectare due to better management. Categorywise and zonewise, energy input and output are shown in Figs. 6 and 7, while Fig. 8 depicts the inverse relationship between productivity and output/input ratio. The yield per hectare plotted in Fig. 9, corroborates the earlier findings on small and marginal farmers.

6.6. Factors affecting the level of energy consumption in agriculture

Earlier discussions showed that bullock power (BH), human power (HH), seed (S), FYM and inorganic fertilisers (F) are the major components in energy input. In order to see the variation in yield due to the consumption levels of these factors, regression analyses were performed and the results are given in Table 8. This analysis is performed first with all data

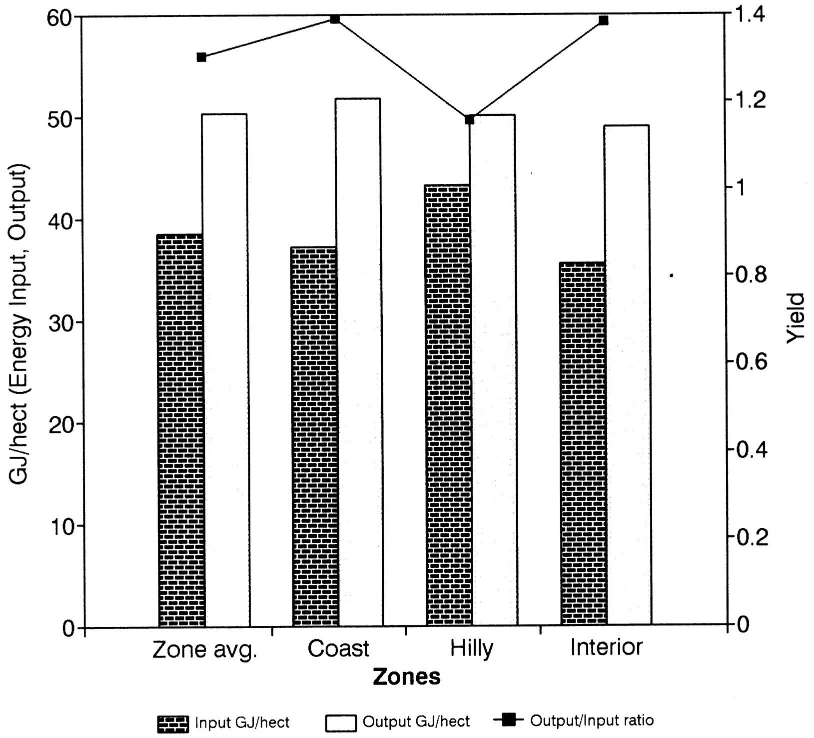

Fig. 4. Energetics in paddy cultivation. Zonewise, Kumta taluk.

Table 6
Energy consumption pattern in paddy cultivation among various categories of farmers (landholding)

LH[a]	N[b]		BH[c]	HH[d]	S[e]	FYM[f]	Fert[g]	Total input	Total output	Paddy out/in	Paddy yield (0.1 ton)
All	1068	Average	6.62	1.46	3.05	27.42	0.03	38.58	50.55	1.31	17.96
		SD	4.51	1.68	2.59	98.12	0.68	98.65	27.79	2.35	9.89
0–0.4	498	Average	6.97	1.71	3.94	33.45	0.03	46.09	59.08	1.28	21.01
		SD	5.17	2.15	3.30	121.50	0.73	122.10	30.65	0.25	10.90
0.4–0.8	313	Average	6.49	1.35	2.50	21.80	0.05	32.19	45.99	1.43	16.31
		SD	4.23	1.14	1.47	60.65	0.87	61.04	18.23	2.74	6.54
0.8–2.0	205	Average	6.54	1.15	2.20	24.03	0.00	33.93	39.93	1.18	14.20
		SD	3.31	1.01	0.94	91.78	0.00	91.83	27.35	2.17	9.73
≥ 2.0	52	Average	4.42	0.99	1.18	16.87	0.00	23.46	38.05	1.62	13.53
		SD	2.16	0.43	0.93	17.46	0.00	18.28	21.99	1.89	7.82

[a] LH — Landholding category.
[b] N — No. of samples.
[c] BH — Bullock hour.
[d] HH — Human hour.
[e] S — Seed.
[f] FYM — Farm yard manure.
[g] Fert — Fertiliser.

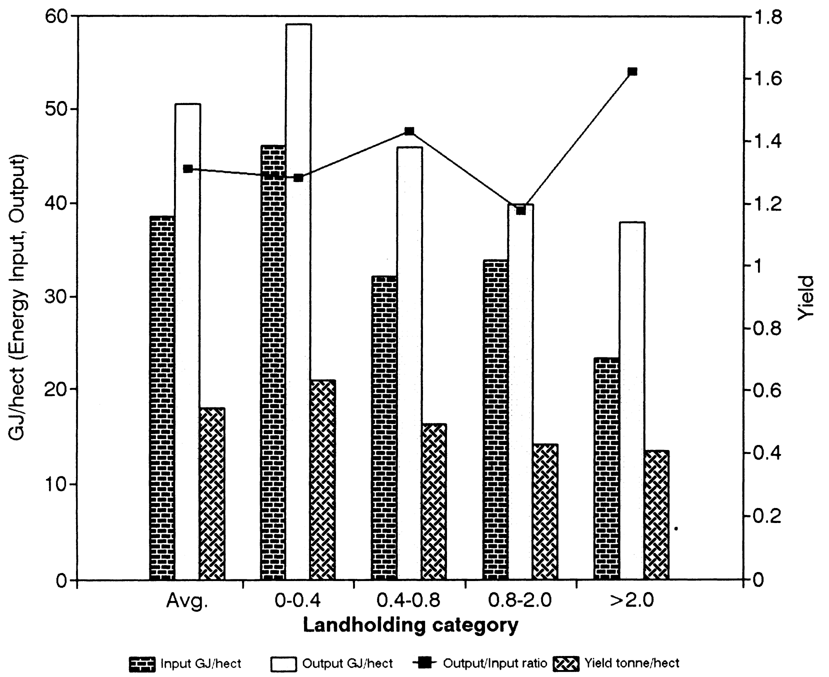

Fig. 5. Energetics in paddy cultivation. Landholdingwise, Kumta taluk.

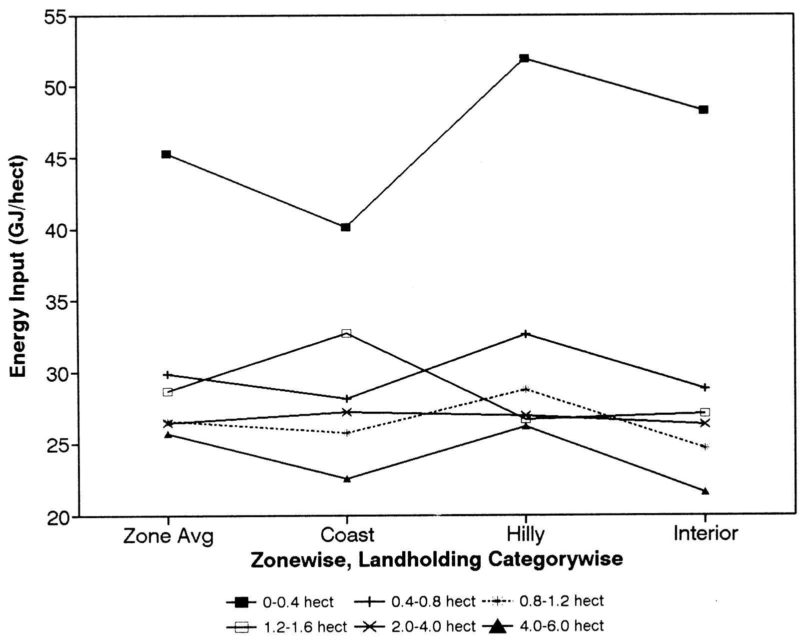

Fig. 6. Energy input (GJ/ha) in paddy cultivation.

Table 7
Energy consumption pattern in various categories of landholding within a region

Zone	N[a]	BH[b]	HH[c]	S[d]	FYM[e]	Fert[f]	Total input	Total output	Paddy out/in	Paddy yield (0.1 ton)
0–0.4 ha										
All	498	6.96	1.71	3.91	32.64	0.03	45.24	56.76	1.25	20.00
Coastal	248	6.67	1.70	3.82	27.84	0.09	40.13	55.65	1.39	19.79
Hilly	160	7.12	1.58	4.06	39.22	0.00	51.94	56.07	1.08	19.94
Interior	90	6.90	2.05	3.55	35.74	0.00	48.23	55.35	1.15	20.07
0.4–0.8 ha										
All	313	6.51	1.35	2.49	21.82	0.05	29.87	48.95	1.64	16.19
Coastal	112	6.55	1.36	2.45	17.80	0.00	28.15	47.02	1.67	16.73
Hilly	101	6.40	1.42	2.58	29.66	0.00	32.64	54.37	1.67	15.72
Interior	100	6.57	1.28	2.46	18.35	0.15	28.81	45.49	1.58	15.37
0.8–1.2 ha										
All	97	6.58	1.23	2.38	16.40	0.00	26.60	41.27	1.55	14.67
Coastal	40	6.93	1.11	2.43	15.30	0.00	25.77	39.02	1.52	13.87
Hilly	30	5.72	1.15	2.37	14.36	0.00	28.79	46.01	1.60	16.36
Interior	27	7.04	1.50	2.33	20.08	0.00	24.66	37.71	1.53	14.02
1.2–1.6 ha										
All	75	6.49	1.06	1.93	19.20	0.00	28.69	36.67	1.28	13.04
Coastal	23	6.76	1.03	1.95	23.00	0.00	32.74	41.48	1.27	14.75
Hilly	29	7.02	1.26	1.82	16.61	0.00	26.72	35.68	1.37	12.69
Interior	23	5.56	0.85	2.05	18.66	0.00	27.12	33.16	1.22	11.78
1.6–2 ha										
All	33	6.59	1.12	2.29	20.87	0.00	30.88	45.06	1.46	12.35
Coastal	12	6.62	1.31	1.87	21.82	0.00	31.62	48.63	1.54	15.42
Hilly	8	6.09	1.07	2.53	22.91	0.00	32.60	47.26	1.45	11.17
Interior	13	6.87	0.98	2.53	21.25	0.00	31.63	44.12	1.40	10.48
2–2.4 ha										
All	25	5.55	1.26	1.49	24.77	0.00	33.07	39.49	1.75	14.04
Coastal	11	5.61	1.20	1.31	21.82	0.00	29.95	30.19	1.43	10.73
Hilly	4	6.69	1.49	1.26	26.52	0.00	35.97	51.72	1.48	18.39
Interior	10	5.03	1.24	1.78	27.30	0.00	35.35	44.82	2.20	15.94
2.4–4.0 ha										
All	11	4.56	0.85	1.58	19.50	0.00	26.49	47.74	1.90	18.52
Coastal	5	5.09	0.96	1.59	19.62	0.00	27.25	55.25	2.03	19.65
Hilly	4	3.77	0.67	1.76	20.78	0.00	26.99	51.15	1.90	18.19
Interior	2	4.83	0.91	1.61	19.03	0.00	26.38	46.75	1.77	17.72
4.0–6.0 ha										
All	16	2.55	1.41	1.51	20.19	0.03	25.68	46.47	1.81	17.69
Coastal	9	2.45	0.65	1.42	18.01	0.00	22.53	42.95	1.91	19.15
Hilly	5	2.78	0.72	1.29	21.36	0.05	26.20	47.62	1.82	18.90
Interior	2	2.44	0.56	1.33	17.20	0.03	21.56	38.70	1.80	15.02

[a] N — No. of samples.
[b] BH — Bullock hour.
[c] HH — Human hour.
[d] S — Seed.
[e] FYM — Farm yard manure.
[f] Fert — Fertiliser.

points and later by partial removal of scatter (i.e. removal of data points beyond the (Average $\pm$SD)).

To investigate the factors responsible and their contributions for variations in yield, stepwise regression analysis is performed zonewise (Table 9) and landholdingwise (Table 10) by adding the variables one by one. Standardised regression coefficients {(X coefficient)(SD of X variables)/(SD of Y variables)} have also been computed, which help in identifying the importance of each variable in the least square formula. These values for the coastal zone, Land (0.418), BH (0.107), HH (.0184), S (0.176), FYM (0.119) and F (0.00085), show that FYM, S, L and BH contribute significantly to the variation of Y. Similar coefficients computed for the hilly zone, Land (0.167), BH (0.004), HH (0.114), S (0.123) and FYM (0.0945), show that HH contribute to Y. In all these cases, the variable land, also contributes significantly (depending on its nutrient status) in the variation of paddy yield. This trend continues even with normalised variables, that is $Xi = (Xi-X\text{avg})/X$ SD and $Yi = (Yi-Y\text{avg})/Y$ SD.

Based on the experience in the field and discussions with progressive farmers, the results are interpreted as:

1. Variation in yield due to variable land is attributed to salinity and varying nutrient content of soil across the zones.
2. High dung availability due to higher livestock density and good management practices have resulted in higher yield in the coast. While the interior zone has a scarcity of green manure and dung availability, the FYM contribution in the hilly zone is significant.

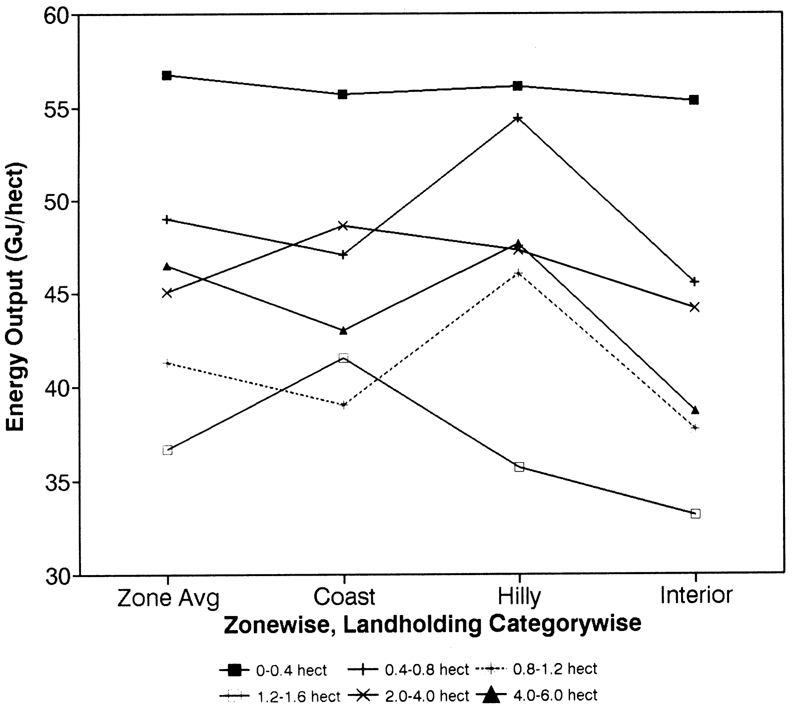

Fig. 7. Energy output (GJ/ha) in paddy cultivation.

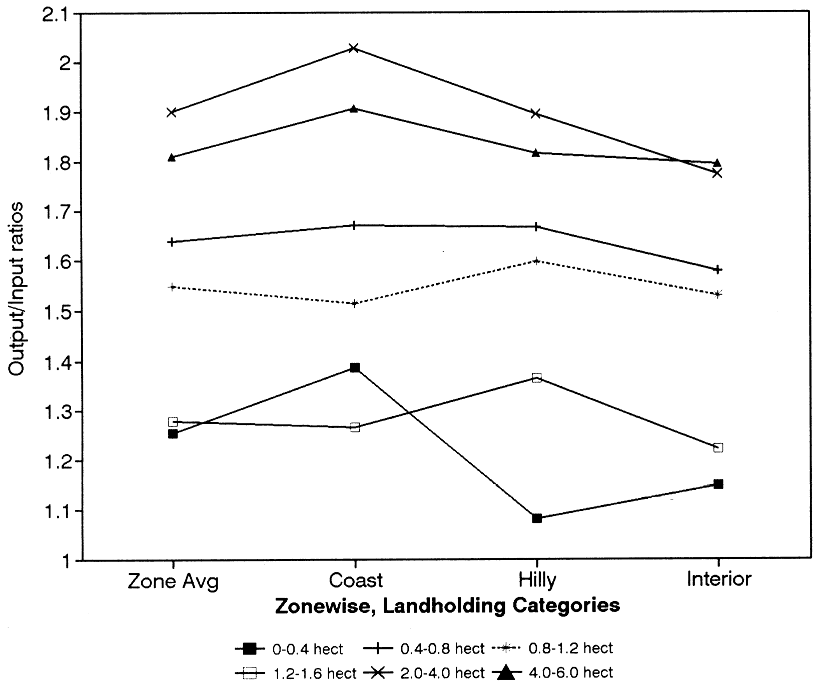

Fig. 8. Output/input ratios for various categories of landholding.

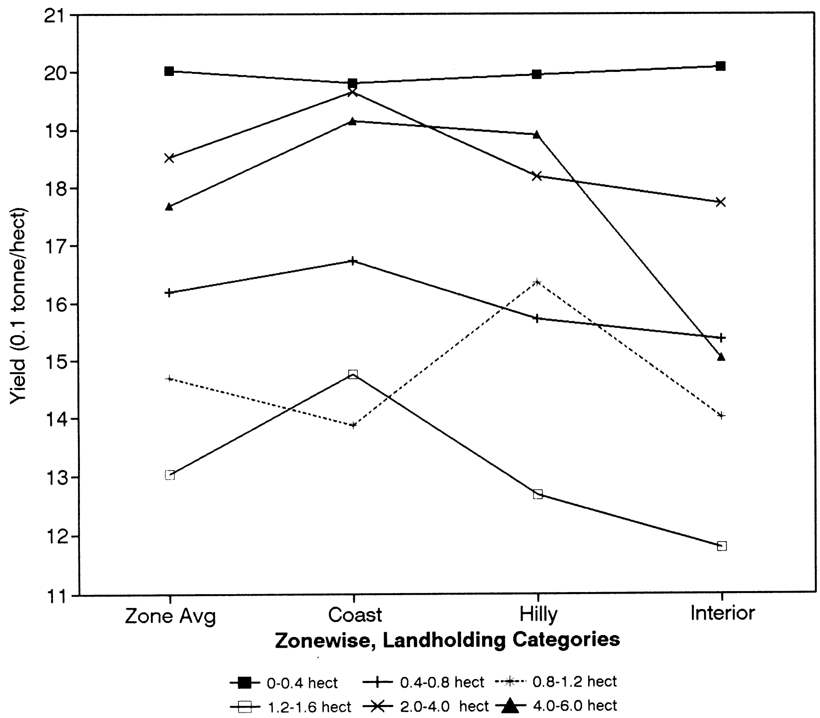

Fig. 9. Paddy yield (0.1 ton/ha).

3. Usage of high yield paddy, improved paddy or mixture of both may contribute towards yield. The high yield variety demands more soil nutrients than local varieties, but dwindling resource base in the form of green manure etc. has contributed to further decline in the yield. Changes in physical and chemical properties of soil, such as, changing quality and quantity of organic matter and tilling of land, also play a role in declining yields. Apart from this, erratic and untimely rainfall, salinity and waterlogging have also contributed to the variation in yield.

7. Conclusions

1. Paddy yield showed a decline from 3.3 (1980–1981) to 1.9 (1992–1993) ton/ha in spite of continued use of HYV and greater application of inorganic fertiliser (26.6% increase) and

Table 8
Regression analyses of yield and various energy input parameters

Zone	N[a]	Dependant variable (Y) (ton/ha)	Independent variable/s (X)	R^{2}[b]	Std. error of Y est.	Probable relationship
Coastal	397	Yield	L[c] (ha)	0.209	4.246	$y = 0.8233 + (-0.0939)$ L
			BH (GJ/ha)[d]	0.086	4.336	$y = 0.689 + (0.0516)$ BH
			HH[e] (GJ/ha)	0.101	4.320	$y = 0.6977 + (0.197)$ HH
			S (GJ/ha)[f]	0.257	4.196	$y = 0.6017 + (.2931)$ S
			FYM (GJ/ha)[g]	0.386	4.005	$y = 0.6955 + (0.01146)$ FYM
			Input (GJ/ha)	0.398	3.983	$y = 0.6728 + (0.0118)$ Input
Hilly	342	Yield	L (ha)	0.231	4.098	$y = 0.8106 + (-0.1160)$L
			BH (GJ/ha)	0.056	4.195	$y = 0.6895 + (0.0293)$ BH
			HH (GJ/ha)	0.172	4.139	$y = 0.6171 + (.4480)$ HH
			S (GJ/ha)	0.203	4.114	$y = 0.6179 + (0.2010)$ S
			FYM (GJ/ha)	0.116	4.173	$y = 0.7084 + (0.002470)$ FYM
			Input (GJ/ha)	0.123	4.170	$y = 0.7030 + (0.00271)$ Input
Interior	329	Yield	L (ha)	0.377	3.093	$y = 0.8463 + (-0.17822)$ L
			BH (GJ/ha)	0.161	3.295	$y = 0.6282 + (0.0755)$ BH
			HH (GJ/ha)	0.105	3.320	$y = 0.6895 + (0.914)$ HH
			S (GJ/ha)	0.321	3.162	$y = 0.5986 + (0.2261)$ S
			FYM (GJ/ha)	0.111	3.338	$y = 0.7101 + (0.00024)$ FYM
			Input (GJ/ha)	0.107	3.337	$y = 0.7063 + (0.00074)$ Input

[a] N — No. of samples.
[b] R — Correlation co-efficient.
[c] L — Land (ha).
[d] BH — Bullock hour (GJ).
[e] HH — Human hour (GJ).
[f] S — Seed (GJ).
[g] FYM — Farm yard manure.

Table 9
Regionwise analysis of factors affecting the yield in paddy cultivation

Zone	N[a]	Dependant variable (Y) (ton/ha)	Independent variable (X)	R^2[b]	Std. error of Y est.	Probable relationship
Coast	397	Yield	L[c]	0.21	4.25	$y = 0.823 + (-0.0938)\mathrm{L}$
			L, BH[d]	0.22	4.24	$y = 0.784 + (-0.8892)\mathrm{L} + (0.0345)\mathrm{BH}$
			L, BH, HH[e]	0.22	4.24	$y = 0.755 + (0.08645)\mathrm{L} + (0.0296)\mathrm{BH} + ((0.121)\mathrm{HH}$
			L, BH, HH, S[f]	0.29	4.17	$y = 0.641 + (-0.05682)\mathrm{L} + (0.0223)\mathrm{BH} + (0.069)\mathrm{HH} + (0.2297)\mathrm{S}$
			L, BH, HH, S, FYM[g]	0.47	3.85	$y = 0.594 + (-0.0543)\mathrm{L} + (0.032)\mathrm{BH} + ((0.064)\mathrm{HH} + (0.2025)\mathrm{S} + (0.0124)\mathrm{FYM}$
			L, BH, HH, S, FYM, Fert[h]	0.47	3.85	$y = 0.594 + (-0.054)\mathrm{L} + (0.032)\mathrm{BH} + (0.0642)\mathrm{HH} + (0.2025)\mathrm{S} + (0.01235)\mathrm{FYM} + (0.0542)\mathrm{Fert}$
Hilly	342	Yield	L	0.23	4.09	$y = 0.811 + (-0.116)\mathrm{L}$
			L, BH	0.23	4.09	$y = 0.794 + (-0.1132)\mathrm{L} + (0.0146)\mathrm{BH}$
			L, BH, HH	0.27	4.06	$y = 0.716 + (0.1042)\mathrm{L} + (0.00247)\mathrm{BH} + (0.3542)\mathrm{HH}$
			L, BH, HH, S	0.29	4.04	$y = 0.651 + (-0.0863)\mathrm{L} + (0.00492)\mathrm{BH} + (0.291)\mathrm{HH} + (0.1235)\mathrm{S}$
			L, BH, HH, S, FYM	0.31	4.02	$y = 0.646 + (-0.08398)\mathrm{L} + (-0.00247)\mathrm{BH} + (0.2939)\mathrm{HH} + (0.121)\mathrm{S} + (0.00197)\mathrm{FYM}$
			L, BH, HH, S, FYM, Fert	0.31	4.02	$y = 0.646 + (-0.0834)\mathrm{L} + (0.000247)\mathrm{BH} + (0.299)\mathrm{HH} + (0.121)\mathrm{S} + (0.0019)\mathrm{FYM} + (0.0443)\mathrm{Fert}$
Interior	328	Yield	L	0.39	2.85	$y = 0.836 + (-0.1729)\mathrm{L}$
			L, BH	0.42	2.82	$y = 0.761 + (-0.166)\mathrm{L} + (0.06175)\mathrm{BH}$
			L, BH, HH	0.42	2.02	$y = 0.746 + (0.1605)\mathrm{L} + (0.05928)\mathrm{BH} + (0.0568)\mathrm{HH}$
			L, BH, HH, S	0.47	2.75	$y = 0.703 + (-0.0143)\mathrm{L} + (0.02717)\mathrm{BH} + (0.03211)\mathrm{HH} + (0.1435)\mathrm{S}$
			L, BH, HH, S, FYM	0.47	2.76	$y = 0.703 + (-0.143)\mathrm{L} + (0.0247)\mathrm{BH} + (0.0321)\mathrm{HH} + (0.14326)\mathrm{S} + (0.000247)\mathrm{FYM}$

L, BH, HH, S, FYM, Fert	0.47	2.76	$y = 0.703 + (-1433)L + (0.02717)BH + (0.03211)HH + (0.143)S + (-0.2\ E{-}04)FYM + (0.4446)Fert$

[b] N — No. of samples.
[c] R — correlation coefficient.
[d] L — Land (ha).
[e] BH — Bullock hour (GJ).
[a] HH — Human hour (GJ).
[f] S — Seed (GJ).
[g] FYM — Farm yard manure.
[h] Fert — Fertilser (GJ).

Table 10
Reggression analysis (landholding wise) of the factors affecting the yield

LH hect[a]	N[b]	Dependant varible (Y) (ton/ha)	Independent variable (X)	R^{2c}	Std. error of Y est.	Probable relationship
0–0.4	491	Yield	L[d]	0.23	3.24	y^j = 1.047 + (−0.7435)L
			L, BH[e]	0.28	3.20	y = 0.948 + (−0.65)L + (0.06175)BH
			L, BH, HH[f]	0.28	3.20	y = 0.932 + (0.639)L + (0.059)BH + ((0.05187)HH
			L, BH, HH, S[g]	0.30	3.18	y = 0.843 + (−0.4794)BH + (0.0396)HH + (0.079)S
			L, BH, HH, S, FYM[h]	0.31	3.18	y = 0.840 + (−0.476)L + (0.518)BH + (0.0395)HH + (0.0815)S + (0.000494)FYM
			L, BH, HH, S, FYM, Fert[i]	0.31	3.18	y = 0.0841 + (−0.49)L + (0.052)BH + (0.039)HH + (0.082)S + (0.0005)FYM + (0.047)Fert
0.4–0.8	312	Yield	L	0.15	2.47	y = 0.867 + (−0.309)L
			L, BH	0.15	2.48	y = 0.869 + (−0.309)L + (−0.002)BH
			L, BH, HH	0.17	2.47	y = 0.850 + (−0.306)L + (−0.005)BH + ((0.091)HH
			L, BH, HH, S	0.18	2.47	y = 0.865 + (−0.294)L + (−0.005)BH + (0.117)HH + (0.072)S
			L, BH, HH, S, FYM	0.19	2.47	y = 0.858 + (−0.209)L + (−0.007)BH + (0.116)HH + (0.069)S + (0.01)FYM
			L, BH, HH, S, FYM, Fert	0.19	2.48	y = 0.0853 + (−0.282)L + (−0.007)BH + (0.116)HH + (0.069)S + (0.001)FYM + (0.047)Fert
0.8–1.2	96	Yield	L	0.01	2.66	y = 0.57 + (−0.02)L
			L, BH	0.01	2.68	y = 0.574 + (0.02)L + (−0.002)BH
			L, BH, HH	0.06	2.69	y = 0.552 + (0.027)L + (−0.002)BH + (0.072)HH
			L, BH, HH, S	0.24	2.63	y = 0.516 + (−0.064)L + (−0.002)BH + (0.042)HH + (0.368)S
			L, BH, HH, S, FYM	0.29	2.60	y = 0.465 + (−0.027)L + (−0.017)BH + (0.054)HH + (0.343)S + (0.012)FYM
			L, BH, HH, S, FYM, Fert	0.29	2.60	y = 0.465 + (−0.027)L + (−0.017)BH + (0.054)HH + (0.343)S + (0.012)FYM + (0.045)Fert
1.2–1.6	75	Yield	L	0.03	2.66	y = 0.664 + (−0.089)L
			L, BH	0.21	2.62	y = 0.670 + (−0.02)L + (−0.106)BH
			L, BH, HH	0.23	2.63	y = 0.721 + (−0.064) + (−0.114)BH + (0.158)HH
			L, BH, HH, S	0.27	2.62	y = 0.476 + (−0.042) + (−0.119)BH + (−0.156)HH + (0.277)S
			L, BH, HH, S, FYM	0.27	2.63	y = 0.437 + (0.057)L + (−0.0111)BH + (0.143)HH + (0.254)S + (0.005)FYM
			L, BH, HH, S, FYM, Fert	0.27	2.63	y = 0.0437 + (0.057)L + (−0.0111)BH + (0.143)HH + (0.254)S + (0.005)FYM + (0.045)Fert
1.6–2.0	33	Yield	L	0.15	1.3	y = 0.725 + (−0.158)L
			L, BH	0.18	1.38	y = 0.812 + (−0.18)L + (−0.037)BH
			L, BH, HH	0.18	1.40	y = 0.813 + (−0.018)L + (0.037)BH + (0.096)HH
			L, BH, HH, S	0.24	1.41	y = 0.539 + (−0.077)L + (−0.042)BH + (0.15)HH + (0.175)S
			L, BH, HH, S, FYM	0.24	1.43	y = 0.554 + (0.084)L + (−0.042)BH + (−0.022)HH + (0.178)S + (0.001)FYM
			L, BH, HH, S, FYM, Fert	0.24	1.43	y = 0.554 + (0.084)L + (−0.042)BH + (−0.022)HH + (0.178)S + (0.001)FYM + (0.044)Fert
2–2.4	25	Yield	L	0.29	3.57	y = 0.731 + (−0.2222)L
			L, BH	0.29	3.65	y = 0.711 + (−0.225)L + (0.012)BH
			L, BH, HH	0.29	3.73	y = 0.745 + (−0.215)L + (0.072)BH + (−0.309)HH
			L, BH, HH, S	0.30	3.82	y = 0.740 + (0.222)L + (0.059)BH + (−0.17)HH + (−0.1146)S
			L, BH, HH, S, FYM	0.44	3.68	y = 0.786 + (0.232)L + (0.375)BH + (−1.49)HH + (.319)S + (0.047)FYM
			L, BH, HH, S, FYM, Fert	0.44	3.68	y = 0.786 + (0.232)L + (0.375)BH + (1.49)HH + (.319)S + (0.047)FYM + (0.039)Fert
2.4–2.8	27	Yield	L	0.41	2.89	y = 0.935 + (−0.086)L
			L, BH	0.41	2.95	y = 0.921 + (−0.084)L + (0.01)BH
			L, BH, HH	0.50	2.86	y = 0.888 + (−0.054)L + (0.48)BH + (−3.038)HH
			L, BH, HH, S	0.50	2.93	y = 0.847 + (−0.049)L + (0.472)BH + (−3.03)HH + (0.114)S
			L, BH, HH, S, FYM	0.77	2.20	y = 0.465 + (−0.015)L + (−0.165)BH + (−.408)HH + (1.03)S + (0.083)FYM
			L, BH, HH, S, FYM, Fert	0.77	2.20	y = 0.456 + (−0.015)L + (−0.165)BH + (−.408)HH + (1.03)S + (0.083)FYM + (0.038)Fert

All	1059	Yield	L	0.28	3.05	$y = 0.783 + (-0.104)\mathrm{L}$
			L, BH	0.29	3.04	$y = 0.764 + (-0.101)\mathrm{L} + (0.02)\mathrm{BH}$
			L, BH, HH	0.30	3.04	$y = 0.741 + (-0.096) + (0.02)\mathrm{BH} + (0.084)\mathrm{HH}$
			L, BH, HH, S	0.34	2.99	$y = 0.675 + (-0.082)\mathrm{L} + (0.012)\mathrm{BH} + (0.064)\mathrm{HH} + (0.136)\mathrm{S}$
			L, BH, HH, S, FYM	0.34	2.93	$y = 0.671 + (-0.079)\mathrm{L} + (-0.012)\mathrm{BH} + (.054)\mathrm{HH} + (0.133)\mathrm{S} + (0.001)\mathrm{FYM}$
			L, BH, HH, S, FYM, Fert	0.34	2.99	$y = 0.670 + (-0.079)\mathrm{L} + (0.012)\mathrm{BH} + (0.064)\mathrm{HH} + (0.133)\mathrm{S} + (0.001)\mathrm{FYM} + (0.057)\mathrm{Fert}$

[a] LH — Landholding category.
[b] N — No. of samples.
[c] R — Correlation coefficient.
[d] L — Land (ha).
[e] BH — Bullock hour (GJ).
[f] HH — Human hour (GJ).
[g] S — Seed (GJ).
[h] FYM — Farm yard manure.
[i] Fert — Fertilser (GJ).
[j] Dependent variable (Y): yield ton/ha.

pesticides. The HYV yield (ton/ha) changes from 2.5 (1984–1985) to 2.2 (1992–1993), while the improved variety changes from 3.7 (1984–1985) to 1.6 (1992–1993).

Population density varies from 0.35 (hilly), 1.35 (interior) to 5.31 (coastal) persons/hectare, while forest cover changes from 25% (coastal), 76% (interior) to 89% (hilly). Livestock density varies from 0.24 (hilly), 0.70 (interior) to 1.63 (coastal) animals/hectare. There is a positive linear correlation between livestock and human density.

2. Energy input from all sources (such as FYM etc.) is in the range 35.47 (interior), 37.24 (coast) to 43.21 (hilly), the major component being organic (FYM). The hilly zone with 89.78% forest cover and dung yield (kg/animal/day) of 5.82 ± 1.8 is rich in organic matter compared to the coast (forest cover 27.66%, dung yield 3.26) and interior (forest cover 78.14%, dung yield 3.94). The average paddy yield is about 1.73 ton/ha.

   In the coast, total energy input in GJ per hectare varies from 33.22 (< 0.4 ha), 34.65 (0.8–1.2 ha), 26.14 (1.2–1.6 ha) to 19.72 (> 2 ha). Output in GJ per hectare also varies from 56.62 (< 0.4 ha), 39.99 (0.8–1.2 ha) to 38.14 (> 2 ha). The output-input ratio varies from 1.13 (1.2–1.6 ha) to 1.93 (> 2 ha).

   Similar trends are noticed in the interior and hilly zones. In the hilly zone, the input energy varies from 55.95 (< 0.4 ha) to 17.50 (> 2 ha) and the corresponding output varies from 58.36 to 30.64. In the interior zone, the input energy varies from 29.18 (< 0.4 ha) to 19.82 (> 2 ha), while the output varies from 32.87 (0.4 ha) to 28.08 (> 2 ha). Marginal and small farmers have better output per hectare due to better management.

3. It is evident that paddy cultivation mainly depends on organic manure (FYM) which constitutes 70–74% of the total input. Yield in all three zones is dependent on the inherent fertility of soil and successful maintenance of the nutrient cycle. The productivity in all zones is dependent on the levels of input, that is the intensity of agriculture in the form of organic inputs etc. As the field sizes are small and fragmented there are problems in cultivating with the help of tractors, tillers etc. The design of machineries to substitute for manual tasks under such conditions is complex and expensive, which makes mechanisation of agriculture inappropriate.

   New seeds and fertiliser can be bought in any quantity according to farmers' inclination and financial position. However, indiscriminate usage of fertiliser has resulted in a significant reduction in yield over a period of time. Some farmers, who switched to inorganic fertiliser in the early 1980s, have returned to organic farming due to declining yield and water pollution problems.

   This may be due to indiscriminate usage of fertiliser without considering soil condition.

   This study shows that, it is not necessary always to increase the energy inputs in agriculture to get higher production. Initial increments in yield due to energy inputs in the form of fertiliser etc. have dwindled in the later years. In view of these, it is necessary to practice environmentally sound management practices for sustainable agriculture without affecting other components of the ecosystem.

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