SUSTAINABILITY OF AGRICULTURURAL DEVELOPMENT STRATEGY IN INDIA: AN ANALYSIS OF ENERGY INTENSITY

1. Introduction

In India, during the last fifteen years, real GDP growth has averaged around 4.4 per cent per annum while value of output in agriculture has increased at the rate of 2.35 per cent per annum. A trend growth rate of foodgrain production at 2.5 per cent p.a. (which is marginally higher than the rate of growth population) has meant that large scale imports of foodgrains were not required even in a drought year (1987-88). Given the limited scope of area expansion, output growth has been attained through significant increases in agricultural yields. For example, at the all-India level, average yield of wheat has increased from 1307 kgs/ha in 1970-71 to 2046 kgs/ha in 1985-86. while the corresponding figures for rice are 1123 and 1552 Kgs/ha. Similar increases have occured in the case of *jowar*(a coarse cereal) and for sugarcane.

The above increases in crop yields have been achieved mainly on account of significant increases in agricultural inputs in the form of irrigation, High Yielding Variety (HYV) of seeds, chemical fertilizers etc. According to a recent study," it has been noticed that high level of yield as well as high growth rates are primarily associated with high use of modern inputs"(Bhalla and Tyagi, 1989 p.56). At the all-India level area under irrigation increased from 38 million ha in 1970-71 to 69.7 million ha in 1988-89; total area under HYV seeds increased from 15 million ha to 65 million ha and consumption of chemical fertilizers (N+P+K) increased from 2.2 million tonnes in 1970-71 to 9.0 million tonnes of nutrients in 1987-88. In other words, fertilizer consumption increased from 14 Kgs/ha in 1970-71 to 44 Kgs/ha in 1984-85. Over the same period (per 1000 hectares gross cropped area) the number of electric pumpsets have tripled, number of diesel pumpsets have doubled while the number of tractors have increase seven-fold.

This strategy of agricultural development based on concentrating the use of modern inputs in selected irrigated areas has significant economic, social and ecological implications (Chakravarty 1987, Vaidyananthan 1988, Hanumantha Rao 1989).

Although rising energy-intensity of Indian agriculture during the seventies has been noted(Bhatia 1985 Chakravarty 1987,p 56)the empirical research relating energy-use and agricultural growth has been rather limited (Senapati 1976,Bhatia 1985, 1988).Further,no explicit efforts have been made to quantify the macro economic implications of continuing with the current strategy(based on irrigation-seed-fertilizers)to achieve projected growth in agriculture output during the nineties.

According to Chakravarty(1987,p56),"it is an important fact that Indian agriculture has become far more energy-intensive during the seventies as compared with the two previous decades of Indian planning.Electricity sales to the agriculture sector increased from 4.5 billion kwh in 1970-71 to 23.5 bilion kwh in 1985-86,a growth rate of 11.9 percent per annum.Estimated consumption of diesel oil used in tractors and pumpsets has increased from 1.34 million tonnes in 1970-71 to 3.92 million tonnes in 1985-86,a growth rate of 7.5percent per annum.If oil commodities(naphtha plus fuel oils and natural gas)used as feedstock and fuel in production of chemical fertilizers are also included, oil input in agriculture has increased from 2.6 million tonnes in 1970-71 to 10.0 million tonnes in 1985-86, an increase of 280 per cent over a 15 year period.The aggregate(direct & indirect) consumption of energy in Indian agriculture has increased by 10.59 percent per annum over the period 1970-71 to 1985-86.As against that for the same period the growth rate of value of output in agriculture(at 70-71 prices) has been 2.35 percent per annum, giving an elasticity coeficient of 4.5. In other words a 3 per cent per annum growth rate in agricultural output would require an increase of 13.5 per cent per annum in consumption of commercial energy sources **if the same strategy of agricultural development is continued over the next decade or so.**

Further, it is considered that there has occurred a **structural shift in** Indian agriculture as a result of the strategy of intensifying the use of seed-fertilizer technology coupled with mechanisation in selected regions. It is also recognized that significant growth in the agricultural sector has been attained mainly in selected regions and crops and this has been associated with inefficient use of scarce resources such as canal irrigation, groundwater, energy, fertilizers, pesticides, etc.(Bhalla and Tyagi 1989, Gulati 1989) Agricultural price and subsidy policies have encouraged such resource-use and cropping patterns which have resulted in overexploitation of groundwater in some regions and waterlogging and salinity in some other areas. It is now recognized in the research and policy circles that this strategy of agricultural development is not **"sustainable"** in the long run and there is a need to devise policy responses which can lead to a more efficient use of energy, water, land and other natural resources.As pointed out in a recent publication," what we need are technologies which can help improve continuously the productivity , profitability , stability and sustainability of our major farming systems if we are to avert , by the end of the century, serious threats to national food security systems in Asia. ....Technology must be related to what we may call land and water-saving crop husbandry;in other words,enhancement of biological productivity per unit of land, water and time on an ecologically sustainable basis"(Swaminathan,1989 p.3).

The issues of resource management become very important viewed in the context of meeting the growing demands of food, fibre and fuel as well as the objective of removal of poverty. As shown earlier,based on the analysis of past data if the existing strategy of agricultural development is allowed to continue, a growth rate of 3.0 per cent p.a. in agriculture during the 1990s will be associated with a 14.6 percent p.a. growth in electricity consumption and a 13.5 per cent p.a.growth in aggregate commercial energy consumption.This would require significant investments in rural electrification and outflow of foreign exchange on imports of diesel oils and naphtha. Since the energy sector accounts for more than one-third of the total public sector outlay in the plans, it is very unlikely that more financial resources can be shifted to the energy sector without affecting other programs of social welfare.

However, devising policy responses to promote more efficient use of resources requires an understanding of the behaviour of and the constraints faced by millions of farmers, agricultural workers, consumers , entrepreneurs and communities. Since these users of resources respond to changes in market prices (as faced by them) without concern for externalities (i.e. ignoring benefits and costs to the society), administered prices in many cases have encouraged inefficiency and greater resource pressures without meeting the equity objective. For example,low (i.e.subsidised)energy prices mean low returns from energy savings and thus have discouraged investments in energy conservation and renewable energy systems. High subsidies amounting to 80 to 90 percent of the delivered cost of electricity used for groundwater pumping coupled with canal irrigation subsidies of the same order have resulted in significant area under rice cultivation in the North-West region(Punjab,Haryana and West Uttar Pradesh). This has caused waterlogging and salinity in some parts of the Punjab and has resulted in lowering of the groundwater table in Haryana.However ,this type of environmental degradation ,if allowed to continue , will be very costly in economic terms. In this context, economic incentives have to be used to harmonize the economic and resource-use goals.

OBJECTIVES

In view of the above , it is necessary to quantify the relationship between energy consumption and agricultural growth, analyze the factors responsible for such high energy intensity and evaluate policy options to ensure a more sustainable development of the agricultural sector in India. More specifically the objectives of this paper are:

(a) To **estimate** the growth in energy use (both direct and indirect) along with changes in energy intensity of agricultural sector which entails assembling and presenting a consistent set of data on consumption of various forms of energy both direct and indirect;and, to analyze the factors responsible for changes in energy consumption.

(b) To **project:** (i) The macro implications (energy needs and investment requirements) of obtaining additional output and marketed surplus of foodgrains and other agricultural products in the region over the next decade or so if the current pattern continues. (ii) the estimated lowering of the ground water (table) as well as the loss of land due to water logging and salinity,
(iii) Implications for the sustainibility of this strategy of development over time in terms of soil fertility, energy cost, maintenance of ground water table and other ecological indices.

(c) To **evaluate** alternative technologies such as minimum/zero tillage, better water managment, biotechnogy and integrated soil nutrient supply system, etc.

(d) To **suggest** R&D programmes, technology generation and diffusion, pricing policies for crop output, energy and other inputs which would encourage **more sustainable** agricultural development.

SCOPE AND COVERAGE:

Agriculture is predominantly a producer as well as a consumer of energy in many developing countries including India. By providing agricultural residues and animal residues, agriculture makes a significant contribution towards meeting the basic energy needs for cooking, particularly of the rural and urban poor.(Bhatia 1985, 1986,1988, Islam et al,).Although the issue of availability of crop residues and animal residues in the context of changes in crop patterns,varietal shifts and increased mechanisation is very important(Chopra 1989, , the scope of this paper is restricted to the role of agriculture as a consumer of energy only. Further,energy consumption in the agricultural sector should include both commercial and noncommercial sources of energy.Although biomass and animate sources account for a large proportion of energy use in this sector,the data-base for these sources is rather weak.Given the stagnant population of working animals over the last twenty years or so it is safe to assume that most of the additional energy requirements of the agricultural sector are being met by commercial energy sources. Therfore,the analysis in this paper is confined to the use of commercial energy sources namely electricity,diesel oils and other oil products in the agricultural sector.

Energy as input into agriculture can be applied in the form of draft power, irrigation and fertilizers. In the category of draft power we have included the number of tractors operating in those years and the quantity of diesel oil used in running those tractors. As regards irrigation, we have considered the number of diesel pumpsets and electric pumpsets and the consumption of diesel oil and electricity to lift water. We have taken into account the consumption of fertlizers and calculated the quantum of energy products(natural gas,naphtha,fuel oils and coal)used as feedstock and fuel in the production of fertilizers. However, consideration of *indirect inputs of energy into agriculture* has been confined to the energy inputs in fertilizer manufacture and indirect energy used in manufacture and transport of agricultural implements(tractors,pumpsets etc.) have not been included due to paucity of reliable data.

DATA AND METHODOLOGY

Aggrgation of Energy Obtained from Differnt Sources

Commercial energy consumption can be divided into two categories: 1) direct consumption and 2) indirect consumption. Direct energy consumption in agriculture consists of use of diesel oil in tractors and diesel engines and electriity in running electric motors for pumping water. Table 1 presents data on direct and indirect energy consumption into agriculture. Consumption of direct energy consumption has increased 3.5 times during the period 1970/71 to 1985/86 which represnts an average growth rate of 8.1 per cent. Increased mechanization of agricultural operations has taken place in the form of substitution of traditional sources (animal power) by mechanical devices example taractors. In 1976 the stock of tractors were which increased to in 1985/86. A substantial amount of diesel consumption has also resulted from operating irrigation devices like agricultural pumpsets using high speed diesel oil. Electricity consumption, however, is accelerating at a faster pace than diesel consumption. In 1970/71, 1336 thousands tonnes of diesel oil and 4470 million kwh of electricity were consumed in the agricultural sector which in 1985/86 increased to 3923 tonnes of diesel oil and 23532 million kwh of electricity. The relative increase in electricity usage compared to diesel could possibly be attributed to price factors 2. The real price of electricity has declined over time whereas that of diesel oil has moved upwards as evident from Figure 1. In other words the extent of subsidization for electricity has been larger for electricity compared to diesel oil.

Use of commercial fertilizers has also increased dramatically in the last fifteen years. Fertilizers industry is one of the few highly energy intensive industries and fertilizers are exclusively used as input into agriculture. Hence it is imperative to include the energy use in fertilizer as an indirect input into the agricultural sector in additon to the direct consumption of fuels/electricity for farm machinery. Since consumption of fertilizers is increasing at a very fast rate in India the estimation of this indirect energy input in terms of indirect energy consumption presents a realistic picture of thr increasing energy intensity of agricultual production. Indirect energy consumkption in agriculture has increased from 1312 in 1970/71 to 4402 in 1985/86. Additional agricultural output requires high yielding varieties of seed. This in turn requires increasing dosages of chemical fertilizers where large quantities of energy products are used as feed stock and fuel. It is important to include this component of energy in the total energy consumption into agriculture to measure the true energy intensity of the agricultural sector. During the year 1985/86 indirect energy accounted for as much as 42.5 per cent of total energy consumption .as evident from Table 1. Now the question is that how productive has been this increase in the use of energy with respect to agricultural output.We find that agricultural production index has increased at the rate of 2.35 per cent whereas that of total energy has grown at 8.0 per cent over the peroid 1970/71 to 1985/86. consumption of commercial energy in agriculture and real gross value of output (in 70/71 constant prices) from agriculture are represnted in table 1. We have used data on real gross value of output rather than real GDP from agriculture because the latter would have excluded the costs of material inputs (including energy). The energy intensity of the agricultural sector in terms of the different components is depicted in table 2. In other words unit energy consumption in terms of tonnes of oil equivalent (TOE) per thousand crores of rupees (70/71 prices) shows a steady increasing trend since 1970/71. Unit consumption of commercial energy (direct plus indirect) has increased almost 2.5 times over the past 15 year period.

RESULTS

(This section is being written)

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TABLE-1 COMMERCIAL ENERGY CONSUMPTION IN INDIAN AGRICULTURE. (ORIGINAL UNITS)

YEAR	Direct: ELECTRICITY CONSUMPTION in agricult. (Million KWH)	Direct: DIESEL consumption (000 tonnes)	Indirect: INPUT IN FERTILIZERS: ELECTRICITY (Million KWH)	Naphtha (000 tonnes)	Fuel Oils (000 tonnes)	Coal (000 tonnes)	Natural (mn. cub metres
1970-71	4470	1336	2531	806	288	NA	187
1971-72	5006	1459	2791	865	350	NA	196
1972-73	5918	1565	2918	1003	389	NA	201
1973-74	6310	1701	3115	1085	481	NA	179
1974-75	7763	1826	3048	1259	469	NA	318
1975-76	8721	1967	4473	1550	520	NA	463
1976-77	9621	2092	4302	1804	579	NA	663
1977-78	10107	2232	3888	1870	680	NA	673
1978-79	12028	2462	4418	1923	1022	NA	721
1979-80	13452	2638	4256	1914	1111	NA	755
1980-81	14489	2830	4067	1718	1202	858	611
1981-82	15201	3042	5093	2316	1386	2706	991
1982-83	17817	3244	4703	2282	1553	2467	1155
1983-84	18234	3456	5086	2134	1487	2899	1283
1984-85	20960	3692	4342	2365	1464	3900	1603
1985-86	23532	3923	5110	2306	1532	2796	2500
Annual Growth Rate	11.44%	7.46%	4.41%	7.44%	13.00%		18.11

Annual Growth Rate is derived from Semi-log equation for the period (1970/71 to 1985/86).

TABLE-2 COMMERCIAL ENERGY CONSUMPTION IN INDIAN AGRICULTURE.
(in '000 tonnes of oil equivelant)

YEAR	Direct: ELECTRICITY CONSUMPTION in agricult. (1)	Direct: DIESEL consum -ption (2)	Direct: Total (1+2) (3)	Indirect: ELECTRICITY CONSUMPTION (4)	Indirect: INPUT IN FERTILIZERS Naphtha (5)	Fuel-Oils (6)	Coal (7)	Natural Gas (8)	Total (4+5+6+7+8) (9)	TOTAL (direct indirect) (3+9)
1970-71	384	1336	1720	218	806	288	NA	168	1480	3200
1971-72	430	1459	1890	240	865	350	NA	176	1631	3521
1972-73	509	1565	2074	251	1003	389	NA	181	1824	3899
1973-74	543	1701	2243	268	1085	481	NA	161	1994	4238
1974-75	668	1826	2494	262	1259	469	NA	286	2277	4771
1975-76	750	1967	2717	385	1550	520	NA	417	2871	5588
1976-77	827	2092	2919	370	1804	579	NA	597	3350	6269
1977-78	869	2232	3101	334	1870	680	NA	606	3490	6591
1978-79	1034	2462	3497	380	1923	1022	NA	649	3974	7471
1979-80	1157	2638	3795	366	1914	1111	NA	680	4071	7866
1980-81	1246	2830	4076	350	1718	1202	429	550	4248	8325
1981-82	1307	3042	4349	438	2316	1386	1353	892	6385	10734
1982-83	1532	3244	4777	404	2282	1553	1233	1040	6512	11289
1983-84	1568	3456	5024	437	2134	1487	1449	1155	6662	11687
1984-85	1803	3692	5494	373	2365	1464	1950	1443	7595	13089
1985-86	2024	3923	5947	439	2306	1532	1398	2250	7926	13873
Annual Growth Rate	11.44%	7.46%	8.56%	4.41%	7.44%	13.00%		18.11%	12.48%	10.59

Annual Growth Rate is derived from Semi-log equation for the period (1970/71 to 1985/86).

TABLE-3 COMMERCIAL ENERGY CONSUMPTION AND ENERGY INTENSITY IN INDIAN AGRICULTURE

YEAR	Total Energy (direct + indirect) (000 TTOE)	Value of Output in Agriculture (at 70-71 prices) (Rs. billions)	---ENERGY INTENSITY--- -TOE per Rs. Million of Agri. Output- YEAR-WISE	Three years Moving Average
1970-71	3200	175.31	18.25	
1971-72	3521	175.49	20.06	20.74
1972-73	3899	163.15	23.90	22.67
1973-74	4238	176.19	24.05	25.20
1974-75	4771	172.49	27.66	26.89
1975-76	5588	192.92	28.97	30.35
1976-77	6269	182.04	34.44	31.89
1977-78	6591	204.24	32.27	34.04
1978-79	7471	211.03	35.40	36.69
1979-80	7866	185.49	42.40	39.31
1980-81	8325	207.52	40.12	43.95
1981-82	10734	217.57	49.34	47.73
1982-83	11289	210.10	53.73	51.11
1983-84	11687	232.55	50.25	53.16
1984-85	13089	235.89	55.49	54.92
1985-86	13873	235.08	59.01	
Annual Growth Rate		2.35%	6.22%	

Annual Growth Rate is derived from Semi-log equation for the period (1970/71 to 1985/86)

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TABLE-4 ESTIMATED ELASTICITY COEFFICIENTS FOR COMMERCIAL ENERGY CONSUMPTION IN INDIAN AGRICULTURE.

	-Elasticity Coefficient w.r.t.-	
	Gross Value of Agr. Output	Net Value Added in Agriculture
Direct Energy		
Electricity	3.8731 * [7.6789]	3.7515 * [5.0210]
Diesel	2.6125 * [8.5587]	2.5601 * [5.5013]
TOTAL	2.9666 * [8.2891]	2.8963 * [5.3494]
Indirect Energy		
Electricity	1.5956 * [5.4889]	1.5638 * [4.1881]
Petroleum Prod. (fuel oil+naphtha+ +Coal+Natural Gas)	4.6065 * [8.8321]	4.5226 * [5.6224]
TOTAL	4.3280 * [8.8705]	2.8963 * [5.3494]
Total		
Electricity	3.2797 * [7.8723]	3.1674 * [5.1373]
Diesel+Patroleum Products	3.7677 * [8.9115]	3.7005 * [5.6545]
TOTAL	3.6793 * [8.7727]	3.6075 * [5.5796]

Figures in brackets are t-values.
* Significant at 99% level.

TABLE-5 GROWTH OF FERTILIZER CONSUMPTION AND MECHANICAL POWER IN INDIAN AGRICULTURE.

YEAR	FERTILIZER (Kgs./Ha.)	--No's Per '000 Ha. of GCA-- Diesel Pumps	Electric Pumps	Tractors
1970-71	13.61	8.95	9.83	0.56
1971-72	16.08	9.41	NA	0.76
1972-73	17.07	10.09	NA	0.91
1973-74	16.71	10.30	14.37	1.02
1974-75	15.67	11.28	16.04	1.20
1975-76	16.92	11.51	16.33	1.31
1976-77	20.39	12.32	18.14	1.49
1977-78	24.87	12.64	19.15	1.60
1978-79	29.28	13.17	20.59	1.95
1979-80	30.98	14.32	23.64	2.24
1980-81	31.86	14.87	25.32	2.43
1981-82	34.27	15.38	26.32	2.65
1982-83	36.83	16.46	28.61	2.99
1983-84	35.49	16.57	29.73	3.17
1984-85	43.82	17.83	32.79	3.58
Annual Growth Rate	8.70%	4.98%	7.76%	13.19%

Annual Growth Rate is derived from Semi-log equation for the period (1970/71 to 1984/85).