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## **Energy Use and Its Efficiency in Andhra Pradesh Agriculture**

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### I

#### INTRODUCTION

Green revolution in Indian agriculture introduced in the mid-sixties shifted the source of growth from area increase to yield improvement. Irrigation and chemical fertilisers acted as complementary inputs for the new seed technology. Once the entire area is covered under the new seed varieties, the sources of growth are restricted to expansion of irrigation and fertiliser use and changes in the cropping pattern. These changes are likely to intensify the energy use and in some cases, the additional output may not be commensurate with the additional energy. The data on cost and returns would not reveal the true picture of returns for energy use because of the distortions caused to energy prices by subsidies. The analysis based on energy input and energy output, both expressed in the same unit, provides a realistic picture of cost and returns. It is difficult to accept any production process with a lower output than the input unless it is argued that some of the energy used in the production has zero opportunity cost. This paper examines the major changes brought about in the agricultural economy of Andhra Pradesh in terms of irrigation, cropping pattern, and land holding distribution and the implications of these changes on the energy use. The sources of data and methods adopted are presented in Section II. Sections III and IV examine respectively the changes in the structure of Andhra Pradesh agriculture and the variations in energy use and energy efficiency across crops. The relationship between farm size and energy use, especially irrigation energy and the impact of different energy inputs on output are focused in Section V and the major conclusions are presented in Section VI.

### II

#### DATA AND METHODOLOGY

The paper uses the primary survey data collected from 495 cultivating households spread in 20 districts of Andhra Pradesh during 1996-97. The data on inputs and output of agriculture are collected in three rounds to minimise recall bias. Earlier studies focused only on the direct sources of energy (human, animal and mechanical power) and ignored the indirect sources (fertiliser, pesticide, manure and manufacture of machinery). After the sharp increase in the oil prices, indirect energy embodied in the manufacture of fertilisers, pesticides and farm machines was also treated as part of energy used in agriculture. There is no unanimity on the energy contributed by draught animals because of the use of three different methods in the estimation. The first method considers

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the joules of animal feed diverted from human consumption and cultivated fodders grown on land diverted from other crops after adjusting for the energy available from dung. The second method estimates the work output of animals in terms of horse power. Using this concept, a pair of bullocks is assumed to develop one horse power (HP) which implies that a tractor of 35 HP is equivalent to 35 bullock pairs (Bhatia, 1976). This engineering equivalence is considered as an under-estimate of the contribution of work animals and it is argued that replacement ratios are more appropriate according to which one-hour of animal labour is treated as equivalent to 9 mega joules (MJ) (Bhatia and Sharma, 1990). In the third method, the contribution of animal power has been estimated in terms of diesel equivalents or diesel saved (Senapati, 1976). Similarly, human labour is assumed to contribute 0.1 HP per hour (Singh and Singh, 1976). The ICAR sponsored study undertaken by Punjab Agricultural University uses slightly higher coefficients of 0.72 HP for adult male and 0.58 HP for adult female (Singh *et al.*, 1988). Even for animal power, the study adopts 3.76 HP for bullocks of medium size. The coefficients for all inputs, both direct and indirect energy sources, have been taken from this study. Total output and inputs are brought into energy units expressed in joules for selected crops. For the analysis of the entire holding, inputs are converted into energy and output is converted into money value, as certain crop outputs could not be converted into energy. Irrigation also creates difficulties in conversion. Canal or tank irrigation does not require any energy for drawing water, except for the maintenance of canals, whereas well or tubewell irrigation requires energy for drawing water. The cost of maintenance is used for estimating the energy requirement. It is estimated that 10 man-days are needed for each hectare of the command area under canals and 4 man-days for tanks. These requirements are converted into energy units for canal and tank irrigation. For well and tubewell irrigation, we have taken the water requirements of each crop and then converted them into hours of pumping needed. It is assumed that a 3 HP motor is needed for pumping water from a well or shallow tubewell and double that of the former is needed for deep tubewell. This assumption is based on the distribution of electrical motors by horse power in the state and field data also supported it. The state has 16.36 lakh agricultural pumpsets of which about one-half are connected with 3 HP motors, 42 per cent with 5 HP and the remaining are connected with 7 HP and above. The field data have shown that drawing water beyond 200 feet requires more than 5 HP. It has to be noted that energy requirements for creating irrigation infrastructure are ignored in the analysis. However, this creates no bias, if the cost of providing canal or tank irrigation is not substantially higher than for tubewells. The study brought out by the Government of Andhra Pradesh on irrigation sector (Government of Andhra Pradesh, 1996) revealed that the current cost of providing surface irrigation is Rs. 1 lakh per hectare for medium projects and Rs. 86,000 per hectare for minor projects. Our field survey revealed that the cost of irrigating one hectare comes to Rs. 60,000 for tubewells and Rs. 50,000 for wells. However, this difference in creating the asset is ignored because of the complications involved in adjustment.

## III

## GROWTH AND CHANGES IN THE STRUCTURE OF AGRICULTURE

The agricultural sector of Andhra Pradesh has been growing at a constant rate of 2.6 per cent per annum since 1970-71. Because of the low growth in the sixties, the long period growth rate is only

TABLE 1. GROWTH RATES OF NET STATE DOMESTIC PRODUCT OF AGRICULTURE

Period (1)	Annual compound growth rate* (2)
1961-62 to 1970-71	0.81
1970-71 to 1984-85	2.60
1974-85 to 1994-95	2.67
1961-62 to 1994-95	2.10

\* Based on the following Trend Equation fitted for three-year moving averages.

$$\ln \text{NSDPA}_t = 7.779 + 0.0081 t + 0.0179 (t-t_1) D_1 + 0.0007 (t-t_2) D_2; \quad R^2 = 0.96, N = 34$$

(1.91)      (3.05)      (0.12)

where  $D_1 = 1$  for  $t > t_1$  and  $D_1 = 0$  otherwise;  $D_2 = 1$  for  $t > t_2$  and  $D_2 = 0$  otherwise;  $t_1 = 1970-71$  and  $t_2 = 1984-85$ .

TABLE 2. CHANGES IN SOURCES OF NET IRRIGATED AREA

Source (1)	1960-63 (2)	1970-73 (3)	1980-83 (4)	1990-93 (5)	Compound growth rate* (6)
Canal	42.5	48.8	48.6	42.7	1.13
Tank	41.0	29.5	26.2	20.9	-1.15
Tubewell	12.8	18.4	4.4	7.9	4.30
Well	-	-	18.1	24.6	-
Others	3.7	3.3	2.7	4.0	1.40
Total	100.0 (30.38)†	100.0 (30.89)	100.0 (35.59)	100.0 (42.28)	1.11

\* Based on end-points.

† Figures in parentheses are actual area in lakh hectares.

2.1 per cent per annum (Table 1). This low growth rate is the result of the constancy of net area sown and slow growth of net irrigated area at 1.1 per cent (Table 2). Though the expansion of irrigated area is not much, the sources of irrigation have undergone significant changes. The share of groundwater increased from 12.8 per cent during 1960-63 to 32.5 per cent during 1990-93 and the share of tank is reduced from 41 to 20.9 per cent. A major part of the expansion of canal irrigated area is offset by

TABLE 3. PERCENTAGE SHARE OF AREA FOR SELECTED CROPS IN GROSS CROPPED AREA

Crop (1)	Triennium ending			Compound growth rate*
	1972-73 (2)	1982-83 (3)	1992-93 (4)	1970-71 to 1995-96 (5)
Rice	24.8	29.0	29.6	0.51
Millets	38.9	33.7	16.2	-4.84
Pulses	10.8	11.8	12.4	0.72
Surgarcane	1.0	1.3	1.4	1.10
Cotton	2.5	3.5	5.5	4.30
Groundnut	11.6	11.2	18.5	3.11

\* Based on trend equations for three-year moving averages.  
Growth rates are significant at 5 per cent level of significance.

TABLE 4. ANNUAL COMPOUND GROWTH RATES OF AREA OF SELECTED CROPS  
ACCORDING TO SOURCE OF IRRIGATION: 1972-73 to 1996-97

Crop (1)	Canal (2)	Tank (3)	Canal+tank (4)	Well+tubewell (5)	All sources (6)
Paddy	0.34*	-1.74*	-0.35*	3.45*	0.25
Sugarcane	-0.30	0.16	-0.18	5.17*	2.72*
Cotton	3.37*	8.03*	3.53*	13.61*	8.29*
Groundnut	-1.32*	0.23	-1.08	8.52*	4.78*

Based on trend equations for three-year moving averages.  
\* Significant at 5 per cent.

the decline in tank area. Thus out of the additional irrigated area of 12 lakh hectares during the period, wells and tubewells alone account for 83 per cent. Groundwater exploitation has a bias towards medium and large farmers who use water for paddy cultivation and sell excess water to marginal and small holdings at a high price. The small holdings utilise the water only for less water intensive crops like groundnut and cotton. Because of the high energy requirements for drawing groundwater, large holdings are likely to consume more irrigation energy than the marginal and small farmers.

There are significant changes in the cropping pattern. The area under millets has gone down steeply (38.9 per cent to 16.2 per cent). Paddy, pulses, sugarcane, cotton and groundnut have improved their shares substantially (Table 3). Cotton and groundnut have grown at a high rate of 4.3 and 3.1 per cent per annum respectively. Paddy and sugarcane have grown at a lower rate than cotton and groundnut, but they have been shifted from low energy intensive surface irrigation to groundwater irrigation (Table 4).

TABLE 5. ENERGY USE FOR DIFFERENT CROPS

Input (1)	(GJ/ha)					
	Paddy (2)	Other cereals (3)	Pulses (4)	Groundnut* (5)	Cotton (6)	All crops† (7)
Human labour	2.00 (10.3)	1.14 (20.9)	0.82 (16.4)	1.36 (11.8)	1.79 (9.0)	1.60 (11.1)
Bullock labour	0.76 (3.9)	0.87 (16.1)	0.72 (14.4)	1.00 (8.7)	1.05 (5.3)	0.85 (5.9)
Manure	1.97 (10.2)	0.70 (12.9)	0.55 (11.0)	1.28 (11.1)	1.45 (7.3)	1.45 (10.1)
Fertiliser	8.48 (43.7)	2.36 (43.5)	1.48 (29.7)	4.25 (36.9)	10.56 (52.8)	5.99 (41.6)
Pesticide	0.17 (0.9)	0.01 (0.2)	0.09 (1.8)	0.09 (0.8)	2.44 (12.2)	0.28 (1.9)
Tractor	0.22 (1.2)	0.06 (1.1)	0.05 (0.9)	0.08 (0.7)	0.09 (0.4)	0.13 (0.9)
Irrigation	4.42 (22.8)	0.14 (2.7)	0.91 (18.2)	0.72 (6.2)	1.96 (9.8)	2.48 (17.2)
Seed	1.33 (6.9)	0.14 (2.6)	0.36 (7.1)	2.72 (23.6)	0.04 (0.2)	1.55 (10.7)
Total input	19.40	5.42	4.99	11.53	19.99	14.41
Total output	24.14	5.05	8.72	10.16 (14.48)	42.92	20.83
Output/input ratio	1.24	0.93	1.75	0.88 (1.25)	2.15	1.45

\* Since the yield is very low due to crop failure, normal yields as reported by the sample farmers are used. The output and output-input ratios given in parentheses are based on normal yields.

† All crops also include sugarcane in addition to the crops mentioned here.

## IV

## ENERGY CONSUMPTION ACROSS CROPS

The average consumption of energy in agriculture is 14.4 GJ per hectare of which direct energy which comprises human labour, bullock labour, tractor and irrigation accounts for 35 per cent and the remaining 65 per cent is indirect energy consisting of fertiliser, manure, pesticide and seed (Table 5). Cotton and paddy consume the highest quantity of 20 GJ and 19.4 GJ per hectare respectively while groundnut consumes a moderate quantity of 11.5 GJ. Millets and pulses have the lowest level of energy intake at 5.4 and 5 GJ respectively.

Though paddy and cotton have the same level of energy consumption, they differ in the type of energy consumed. Paddy requires more energy for irrigation and cotton requires more energy of plant protection chemicals and soil nutrients. As a result, cotton consumes 15.06 GJ of indirect energy, while paddy requires only 10.66 GJ per hectare. Groundnut is also similar to cotton in high consumption of indirect energy, but it is mainly due to seed which forms an exceptionally high proportion of total input energy (23.6 per cent).

Energy use efficiency varies significantly across crops. Cotton has the highest efficiency with each unit of energy producing 2.15 units of output. On the other hand, paddy has a low energy use efficiency of 1.24, while its energy requirement being the same as that of cotton. Groundnut, with moderate energy requirement, produces 1.25 units per unit of energy input and has the same energy efficiency as paddy.

## V

## FARM SIZE, ENERGY USE AND IMPACT ON OUTPUT

*Source of Irrigation and Energy Use*

Since paddy accounts for a high share of irrigation energy which has four distinct sources with varied energy requirements, its energy efficiency will be sensitive to source of irrigation (Table 6). Paddy cultivated under canal or tank irrigation has high efficiency of 1.5 to 1.6, but when cultivated under groundwater irrigation, its efficiency goes down to 1.2 for open well or shallow tubewell and 0.9 for deep tubewell. Thus, it is desirable to restrict paddy cultivation to surface irrigation and, if necessary, only for open wells and shallow tubewells.

*Farm Size and Energy Use*

The variation in energy use across farm size is examined for paddy (Table 7). The medium and large farmers use more energy than the marginal and small farmers, which is due to steep increase in irrigation energy with the size of land holding. Irrigation energy increases from 2.9 GJ per hectare for marginal farmers to 5.4 GJ per hectare for large farmers. While human labour and fertiliser energy decline with increase in farm size, irrigation energy increases with farm size. This result indicates the

TABLE 6. ENERGY USE FOR PADDY ACROSS SOURCES OF IRRIGATION

(GJ/ha)

Input (1)	Source of irrigation			
	Canal (2)	Tank (3)	Well (4)	Tubewell (5)
Human labour	1.92 (12.2)	2.02 (13.1)	2.13 (10.4)	1.88 (7.2)
Bullock labour	0.47 (3.0)	1.11 (7.2)	0.92 (4.5)	0.48 (1.8)
Fertiliser	9.36 (59.1)	8.39 (54.4)	8.04 (39.3)	8.13 (30.9)
Tractor	0.30 (1.9)	0.15 (1.0)	0.18 (0.9)	0.29 (1.1)
Irrigation	0.16 (1.0)	0.06 (0.4)	5.97 (29.2)	11.94 (45.4)
Total input	15.84	15.43	20.47	26.33
Total output	25.29	23.35	24.31	23.49
Output/input ratio	1.60	1.51	1.19	0.89

\* Figures in parentheses are percentages to total input.

1 GJ (Giga joule) =  $10^9$  joules.

dependence of large holdings on groundwater.

The relation between farm size and energy use is examined with the help of three regression models in which net area sown is the independent variable and per hectare use of total energy or irrigation energy or groundwater energy is used as dependent variable. All the three models (equations 2, 3 and 4 of Table 8) are statistically significant even at 1 per cent level of significance. The results show that as farm size increases, energy use per hectare declines. But the use of irrigation energy or groundwater energy increases more than proportionately. For 1 per cent increase in farm size, energy use per hectare declines by 0.1 per cent whereas for 1 per cent increase in farm size, irrigation energy increases by 1.09 per cent and groundwater energy increases by 1.13 per cent. Thus small farms have more overall energy use, but less irrigation energy use, especially groundwater than large farms. Similarly, it is observed that as farm size increases, energy efficiency declines (equation 1 of Table 8).

It is pertinent to examine whether the increase in energy use per hectare improves or reduces energy efficiency. To examine this aspect, the value of output per unit of energy is regressed on energy use per hectare. The estimated model (equation 5 in Table 8) shows that energy efficiency

TABLE 7. ENERGY USE FOR PADDY ACROSS SIZE OF LAND HOLDING

Input (1)	(GJ/ha)			
	Marginal (2)	Small (3)	Medium (4)	Large (5)
Human labour	2.09 (10.9)	2.02 (10.9)	1.97 (10.1)	1.99 (10.1)
Bullock labour	0.83 (4.4)	0.72 (3.9)	0.91 (4.7)	0.69 (3.5)
Fertiliser	9.12 (47.8)	8.81 (47.7)	8.53 (43.6)	8.15 (41.2)
Tractor	0.22 (1.2)	0.24 (1.3)	0.19 (1.0)	0.23 (1.2)
Irrigation	2.94 (15.4)	3.17 (17.2)	4.36 (22.2)	5.35 (27.1)
Total input	19.10	18.48	19.59	19.76
Output	23.87	25.34	24.59	23.51
Output/input ratio	1.25	1.37	1.26	1.19

\* Figures in parentheses are percentages to total input.

increases with energy intensity.

Energy inputs are clubbed into traditional inputs comprising human labour, bullock labour, farmyard manure, surface irrigation and seed, and modern inputs comprising tractor, groundwater irrigation, fertiliser and pesticide. The contribution of each of the three components for output growth is examined through Cobb-Douglas production function with modern input energy and traditional input energy as input factors (equation 6 in Table 8). The two variables explain 78 per cent of the variation in output and both of them are significant at 1 per cent level. It is found that 1 per cent increase in modern inputs increases output by only 0.37 per cent while the traditional inputs contribute 0.64 per cent. The low contribution of modern inputs may be due to groundwater irrigation which adds more to energy than to output.

## VI

### CONCLUSION

The agricultural sector of the state has been growing at a low rate of 2.1 per cent since the early sixties. The growth of irrigated area is only 1.1 per cent but there is a shift to energy-intensive groundwater irrigation. The cropping pattern too has shifted towards more energy intensive crops.

TABLE 8. RESULTS OF REGRESSION MODELS

Equation No. (1)	Dependent Variable (2)	Constant Term (3)	Regression coefficients of				R <sup>2</sup> (8)
			LNNSA (4)	LNEINPTR (5)	LNEINPMOD (6)	LNEINPHE (7)	
1.	OUTINRAT	1.6277	-0.2334 (2.84)				0.016 (8.05)
2.	LNEINPHE	9.5454	-0.0975 (5.55)				0.059 (30.84)
3.	LNEIRRGR	1.0181	1.1298 (4.57)				0.041 (20.91)
4.	LNEIRRIG	4.2236	1.0886 (5.78)				0.064 (33.43)
5.	OUTINRAT	-5.6930				0.7597 (3.74)	0.166 (13.95)
6.	LNOUTPUT	0.9069		0.6386 (15.94)	0.3726 (12.98)		0.779 (868.74)

Notes: OUTINRAT : Output value/total input energy.  
LNNSA : Logarithm of net sown area.  
LNEIRRIG : Logarithm of energy input of irrigation.  
LNEIRRGR : Logarithm of energy input of irrigation from groundwater.  
LNEINPHE : Logarithm of total energy input per hectare.  
LNEINPTR : Logarithm of traditional energy input from traditional sources.  
LNEINPMOD : Logarithm of modern energy input from modern sources.

Figures in parentheses below the regression coefficients are t-ratios.

Figures in parentheses below the R<sup>2</sup> are F-values.

Paddy and cotton have total energy consumption of 20 GJ per hectare and pulses and millets have very low consumption of 5 GJ per hectare. While paddy consumes more direct energy in the form of irrigation, cotton consumes in the form of plant and soil nutrients.

The results show that small farms use more energy per hectare and their energy efficiency is also high as compared to large farmers. However, large farms use more irrigation energy, especially groundwater, because of the scale bias of this source of irrigation. Another important finding is that the contribution of traditional inputs is higher than that of the modern inputs. This is mainly because of the high energy intensity of groundwater irrigation.

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