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ENERGY REQUIREMENT FOR TILLAGE OPERATIONS AND A DYNAMIC MODEL OF MECHANIZATION : THE CASE OF BANGLADESH

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ABSTRACT

Energy requirements for tillage operations vary with crop, soil condition and the availability of draft animals. But draft animals are short in supply. So, mechanization of tillage operations is being encouraged by planners to overcome draft shortages. A simple system dynamics model is presented in this paper to assess the mechanization requirements of tillage operations in order to supplement the draft power shortage in Bangladesh and the model was simulated using professional DYNAMO on a micro computer. The potential implications of the model and its utility for the planning process are also discussed.

INTRODUCTION

Bangladesh is at the initial stage of agricultural mechanization. Land preparation in Bangladesh is done predominantly by using traditional animal drawn country ploughs and to a limited extent by using tractors and power tillers. Draft animals are in short supply in both quantity and quality. Recent shortage of draft power and privatization of mechanized cultivation have evolved a draft power market for hiring services of tractors and power tillers under the influences of complex socio-economic interactions.

Several studies have been conducted on energy requirement of the major crops in Bangladesh (Bala, 1980, Bala et al, 1980, 1989a and 1989b and Sarker, 1981). These studies were conducted at micro-level and do not consider the tillage energy requirement both by farms sizes and regions. The potentiality of a model as a tool for policy planning for rural energy systems was demonstrated by Alam et al, 1980. The purposes of this paper are to present : (i) the energy use pattern for tillage operations by farm sizes and regions and (ii) a simple dynamic model to compute the mechanization requirements of tillage operations.

MATERIAL AND METHODS

Energy requirements for tillage operations

For this study Bangladesh was divided into four almost internally homogeneous strata and four regions, Jessore, Mymensingh, Rajshahi and Sylhet were selected by a combination of random and purposeful sampling. This selection was based on physical conditions of soil, agro-ecological variations, cropping pattern and agricultural practices. Three categories (strata) of farmers small, medium and large farm sizes were sampled for interview on agricultural operations and relevant practices. These farm sizes are : (i) small farms 0.5 - 1.0 ha, (ii) medium farms 1.0 - 2.0 ha and (iii) large farms 2.0 ha and above. To select the farmers, three stratified clustered sampling was employed. The stages are the region, the village and farm size. These stratum were formed for better estimate of the stratum mean from a small sample in that stratum.

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Twenty four villages in the regions of Jessore, Mymensingh, Rajshahi and Sylhet were selected and a total of 216 farmers were interviewed. The field level study was conducted from December, 1988 to August, 1989.

To compute the energy requirements for tillage operations, the energy expenditure by man and bullock are considered to be 1235 kJ/hr and 4693 kJ/hr respectively. These parameters were determined considering both direct (energy intake per day) and indirect (energy requirement to maturation distributed equally over entire working life) energy consumption.

A simple dynamic model for agricultural mechanization of tillage operations

Agricultural mechanization is a dynamic system and it changes with place and time by the interactions of socio-economic, biological, technological, and agro-ecological conditions. The planning of such a complex system is a formidable challenge. Case studies can be used for short term planning, but the most inexpensive method to aid in the policy planning is the System Dynamics. System Dynamics is a methodology for development of a computer model for complex socio-economic systems for analyzing the dynamic behaviour of the system for alternative courses of actions.

The agricultural mechanization system consists of an integrated crop and animal production system. The irrigation expansion policy is assumed to be the general trend of an increase of irrigated area at the rate of 8.5% (Navin and Khalil, 1989). The source of draft power is cattle and the cattle population links the production rate and consumption rate through the price. The availability of draft animals is also influenced by the availability of rice straw. Available draft animals and cultivated area determine the draft power/ha. The draft power deficit/ha multiplied by cultivated area (ha) gives the draft shortage. This shortage is converted into equivalent number of tractors or power tillers required to supplement thedraft power shortage. The causal loop diagram of the agricultural mechanization system is shown in Fig.1.

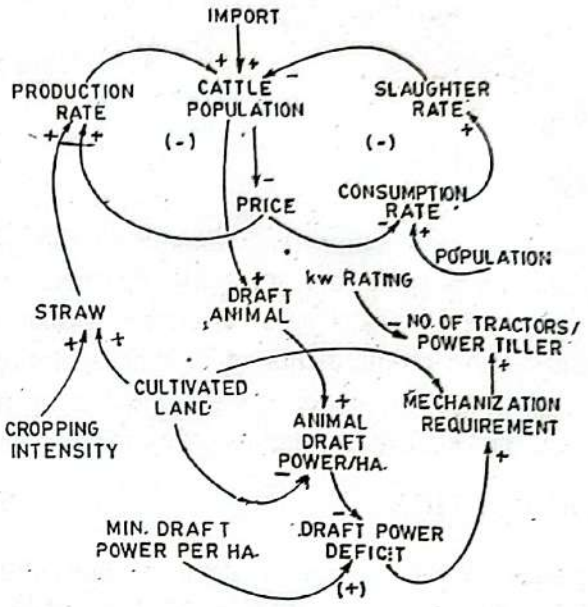

FIG. 1 CAUSAL LOOP DIAGRAM OF THE AGRICULTURAL MECHANIZATION SYSTEM IN BANGLADESH FOR TILLAGE OPERATION.

The relationships of the model were expressed in DYNAMO equations and model was simulated using professional DYNAMO on a micro computer.

RESULTS AND DISCUSSION

Energy requirements for tillage operations

Table 1 shows the energy requirements for tillage operations for major crops grown by three categories of farmers in the regions of Jessore, Mymensingh, Rajshahi and Sylhet. The requirements of energy for tillage operations vary with crops, categories of farmers and regions. The variations of energy requirements for the crops are mainly due to the soil type, and availability of draft animals for land preparation. The energy requirements for tillage operations in the villages of Jessore and Rajshahi are relatively low because of light and easily worked soil. The high requirements of energy for tillage operations in the villages of Mymensingh and Sylhet may be attributed to the fact that the soils are relatively heavy. The relatively low value of energy

requirement for boro production in Sylhet is mainly due to the fact that the major portion of the boro is grown in the low land areas (marshy land) of this regions with limited energy expenditures on tillage operations. Table 2 shows the draft power availability in kW/ha for three groups of farmers in Jessore, Mymensingh, Rajshahi and Sylhet. The distribution of animal draft power is not uniform for the regions and farms. The draft power availability of Jessore (0.20 kW/ha) is lower than the requirement atany standard. It is also interesting to note that there exists a draft power market in Jessore and Mymensingh for preparation by using tractors and power tillers (Table 3). The tractor/power tillers are also being used by the small farmers in Jessore to supplement the shortage of draft power for tillage operations. This confirms the actual existence of animal draft power shortage in Jessore region.

Rable 1. Energy requirements for tillage operations using animal draft power (GJ/ha)

Region	Categories of farms	Crops					
		Aus	Aman	Boro	Wheat	Jute	Sugarcane
Jessore	Small	3.14	2.80	3.23	3.23	3.91	4.76
	Medium	3.14	2.55	2.63	2.80	4.08	4.42
	Large	3.48	2.97	2.72	4.16	3.99	4.42
	Average	3.20	2.80	2.80	3.91	3.99	4.50
Mymensingh	Small	4.59	4.59	4.16	4.67	3.99	-
	Medium	4.08	3.91	4.33	4.33	4.67	-
	Large	3.48	4.33	4.08	4.59	4.50	-
	Average	4.08	4.25	4.16	4.50	4.42	-
Rajshahi	Small	2.72	2.63	2.97	3.91	2.80	3.99
	Medium	3.23	3.06	3.31	4.25	3.40	4.25
	Large	3.65	3.31	4.16	4.25	3.74	4.67
	Average	3.23	2.97	3.48	4.16	3.31	4.33
Sylhet	Small	4.50	4.67	3.65	5.69	5.01	-
	Medium	4.16	3.99	3.14	5.35	-	-
	Large	4.16	3.99	2.63	5.35	-	-
	Average	4.33	4.25	3.14	5.44	5.01	-

Table 2. Animal draft power availability (kW/ha) and percentage of cows used as draft animals in Jessore, Mymensingh, Rajshahi and Sylhet

Item	Categories of farms	Crops			
		Jessore	Mymensingh	Rajshahi	Sylhet
Draft power availability (KW/hr)	Small	0.24	0.43	0.47	0.73
	Medium	0.21	0.29	0.24	0.31
	Large	0.16	0.23	0.18	0.20
	Average	0.20	0.32	0.30	0.41
Percentage of cows used as draft animal	Small	0.00	57.10	10.00	25.40
	Medium	7.40	39.50	5.20	12.70
	Large	0.00	38.00	2.40	17.70
	Average	2.46	44.90	5.80	18.60

NOTE : Giles (1987) suggest a minimum of 0.373 kW/ha
Gil (1991) represents a minimum of 0.23 KW/ha

Table 3. Percentage utilization status of tractors and power tillers

Categories of farms	Region of			
	Jessore	Mymensingh	Rajshahi	Sylhet
Small	50.0	11.1	0.0	0.0
Medium	44.4	5.5	0.0	0.0
Large	50.0	0.0	0.0	0.0

A simple model of agricultural mechanization of tillage operations

Simulated population and cattle population are shown in Fig.2. Simulated population is in excellent agreement with that reported by Navin and Khalil (1989) and the simulated cattle population is also in good agreement with the projected cattle population by Dickey and Huque (1986). The population increases at a constant rate of 2.45%. The simulated cattle population is not far removed from the projected cattle population by Dickey and Huque (1986) and the trend is exactly similar. However, the simulated cattle population shows a cyclic fluctuation of time period 13.5 years. This provides a suspect that the cattle cycle in Bangladesh might be a limit cycle oscillation.

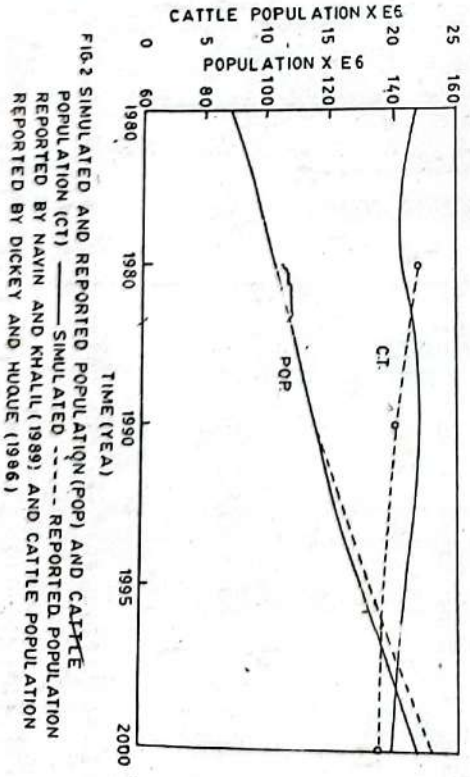

FIG.2 SIMULATED AND REPORTED POPULATION (POP) AND CATTLE POPULATION (CT) —— SIMULATED ----- REPORTED. POPULATION REPORTED BY NAVIN AND KHALIL (1989) AND CATTLE POPULATION REPORTED BY DICKEY AND HUQUE (1986)

Simulated available draft power, draft power per ha and draft power shortage are shown in Fig>3. The patterns of the dynamic behaviour of available draft power and draft power per ha are similar to those of cattle population. Again, Fig.3. shows that there is a fluctuating shortage of draft power. The mechanization requirement to supplement the draft power shortage is considered to be the difference between the minimum requirement of draft power in kW (based on 0.23 kW per ha) and the actual draft power available in kW. The requirements of 9.1 kW power tillers and 33.5 kW tractors to supplement the draft power shortage during the simulated period are shown in Fig.4. The requirements of power tillers and tractors for mechanization of tillage operations fluctuate with time and there is an increasing trend of these requirements. This implies that mechanization requirement of tillage operations in Bangladesh to supplement the draft power shortage is dynamic and increasing with time.

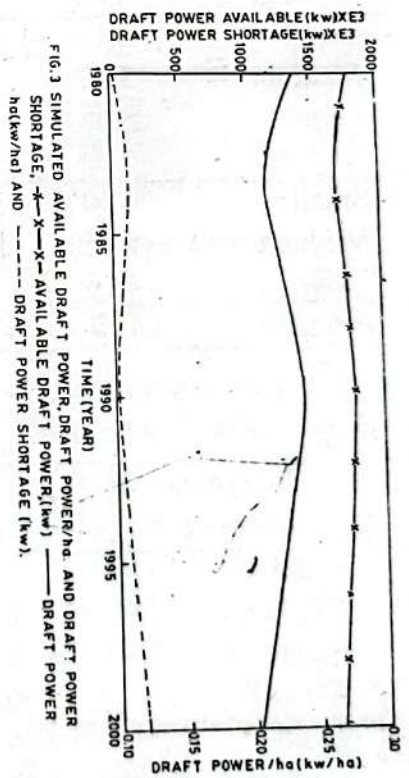

FIG.3 SIMULATED AVAILABLE DRAFT POWER, DRAFT POWER/ha AND DRAFT POWER SHORTAGE, -X-X- AVAILABLE DRAFT POWER(kw) —— DRAFT POWER ha(kw/ha) AND ----- DRAFT POWER SHORTAGE (kw).

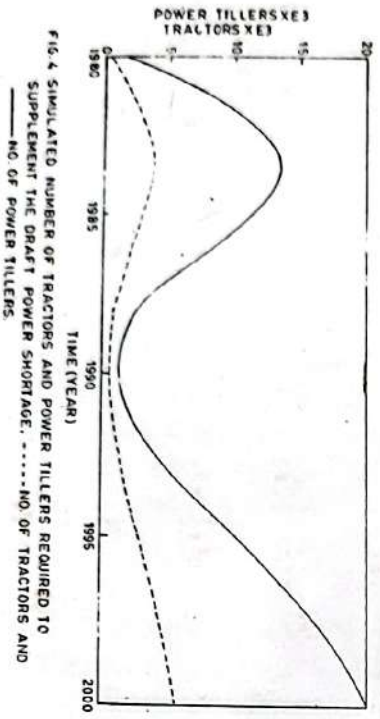

FIG.4 SIMULATED NUMBER OF TRACTORS AND POWER TILLERS REQUIRED TO SUPPLEMENT THE DRAFT POWER SHORTAGE. -----NO. OF TRACTORS AND ——NO. OF POWER TILLERS.

CONCLUSIONS

Field level studies show that there exists a shortage of draft power both in quantity and quality in Bangladesh and System Dynamics model is proposed to assess the agricultural mechanization requirements of tillage operations to supplement the draft power shortage in Bangladesh. Logical consistency of structure and the good agreement between simulated and recorded results validates the model. Although the model has been validated against the available time series data, it suffers from the details for assessing the different mechanization policies such as the effects of the expansion of irrigated area, importation of draft animals and/or tractorization to supplement the draft power shortage and population control measures on agricultural production, per capita food availability and employment. Much additional work remains to determine the sensitivity of the parameters, update the data and refine the model in detail such as extending the model to include the detail crop production, population and employment submodels for its use as a tool to perform the policy analysis for agricultural planning. This model is not intended to replace the policy planner rather it is expected to provide better understanding and greater insight of the agricultural mechanization to its policy planners.

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