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rates. Of these, hardly two men worked both for agricultural operations and for maintenance of animals. Most of the labour utilized for the maintenance of animals was by family members. Only about 1.6 standard man-hours were utilized per day per animal excluding the time spent for taking the animals for grazing. The extent of involvement in the maintenance of animals was almost in equal proportion by a man and woman, the child labour being a small fraction and mostly utilized for grazing operation. It was observed that about 120 and 98 man-days were utilized on rearing a female and male cross-bred calf respectively from birth to three years of age. About 75 man-days were utilized for a non-descript calf of either sex upto three years of age.

PROSPECTS OF INCREASING INCOME AND EMPLOYMENT ON MIXED FARMS

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Taking into consideration the facts that for the majority of farmers land is the major limiting factor in raising their income and employment; as milk production enterprises require relatively less land and more labour to generate a given level of income as compared to foodgrain crops, mixed farming system suits the small farms; milk and milk products are the chief source of animal proteins in the average Indian diet; the average per capita availability of milk is far below the minimum requirements as per nutritional standards; with the increase in population and real income the demand for milk would increase at a much faster rate ensuring its remunerative price, the future of dairy industry seems to be quite promising. On the mixed farms in the country, the number of cattle and buffaloes is mainly determined by the availability of fodders (crop by-products). At the individual farm-firm level, the availability of fodders could be augmented through the purchases from the other farms. However, due to the very bulky nature of roughage fodders, its supply can not be augmented easily at the aggregate (macro) level through purchases. Therefore, at the aggregate level, the total quantities of fodders required for feeding the livestock must not exceed the total quantities of the same available (produced) in the area. With these considerations this paper attempts to determine the extent to which the farm income and employment could be increased on typical mixed farms as well as the aggregate of the area as a whole from the optimal crop and milk production plans derived by using the common and improved production technologies.

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DATA AND METHODOLOGY

Data

The data regarding the input-output coefficients for various crops and milk production activities, resource supplies, consumption needs of the staple food-grains for the farm family and other relevant information have been taken from the farm business records of 124 randomly selected farmers from a cluster of five villages of Narona centre in district Aligarh for the years 1974-76. These records were maintained for one of the research projects "Comparative Economics of Milk Production in the Dairy Development Project Area, Aligarh"[1] of Pantnagar University. From the list of all the farmers of the selected cluster who maintained at least one milch animal, 30 small (below one hectare (ha.)), 60 medium (1 to 3 ha.) and 34 large (above 3 ha. of operational holdings) farmers were selected in probability proportion. The data on milk yields and quantities of green and dry fodders and concentrates fed to different categories of animals were recorded after actual weighment regularly once a fortnight while on other particulars like the lactation length, dry period, labour hours spent on feeding, grazing, management, etc., charges for veterinary services and medicines, prices of feeds, seeds, fertilizers and other agricultural inputs as well as yields and prices of crop enterprises were collected by direct observation and careful enquiry. For deriving the dependable optimal plans, however, it is necessary to have a high degree of quantitative and qualitative accuracy in the basic input-output data and availability of limiting resources. As the procurement of such data is time consuming and costly, most of the studies conducted on the subject suffer from such weakness in the data, from which the set of data used in the present study is almost free.

The technical coefficients for the common production processes were synthesised by taking the means of respective farm size-groups. To derive the coefficients for the improved production processes, the farm business data of the top 10 per cent sample farmers were used in the case of crops whereas in the case of the milch animals, the input-output coefficients of Murrah buffaloes were considered. The costs incurred and returns obtained from the milch animals during the complete inter-calving period were converted on annual basis to make it comparable with the crop enterprises.

Model

To derive the optimal crop and milk production plans for various farm groups as well as the 'aggregate of area',[2] the profit maximization type of linear programming models of the following matrix form was used:

$$\text{Maximize } Z = C'X$$

$$\text{subject to } AX \begin{matrix} \leq \\ = \\ \geq \end{matrix} B, \text{ and } X \geq 0$$

1. For details, see R. N. Pandey *et al.*, "Dairy Development Extension Project: A Step towards White Revolution", *Indian Dairyman*, Vol. 29, No. 9, 1977, pp. 585-590; R. N. Pandey *et al.*: Economic Analysis of Milk Production under Mixed Farming System in Aligarh District of Uttar Pradesh, Research Report, Department of Agricultural Economics, G. B. Pant University of Agriculture and Technology, Pantnagar, 1979.

2. W. N. Schaller, "Estimating Aggregate Product Supply Relations with Farm Level Observations", in Production Economics in Agricultural Research, AE 4108, University of Illinois, Urbana-Champaign, U.S.A., 1966, pp. 97-109.

where Z is the objective function,
C is an n × 1 vector of returns over variable costs/prices of the production processes/activities,
X is an n × 1 vector of production processes/activities,
A is an m × n matrix of technological coefficients, and
B is an m × 1 vector of resource supplies or other constraints.

Production Processes/Activities

The alternative production processes considered in deriving the optimal plans include all important foodgrain and fodder crops grown under both the common as well as improved production technologies, milch and draught animals, purchase of concentrates and dry fodders, borrowing of working capital, hiring of labour in the case of medium and large farms. The simplex matrix of the model for the 'aggregate of the area' with all technical coefficients and constraints was prepared. Similar matrices were also prepared for the small, medium and large farms.

Resource Availability/Constraints

The important resource constraints in the model include land, irrigation facilities, human labour, working capital, green and dry fodders, concentrates, number of draught animals and *desi* and high-yielding buffaloes[3] and the minimum quantity of foodgrains that must be produced to satisfy the consumption needs of the farm family/area (Table I). The results of the linear programming models were obtained through the electronic computer at the Indian Agricultural Statistics Research Institute, New Delhi.

RESULTS AND DISCUSSION

The estimates of farm income, labour requirement and marginal value productivity (MVP) of milch animals obtained from the optimal plans derived with varying number of milch buffaloes for the small, medium and large farms are presented in Table II. On an average, 9 man-days of human labour per month were employed for feeding, grazing and management of each milch animal unit and 7.5 man-days per month for each pair of bullocks.

Small Farms

In the case of small farms (0.6 ha.), the actual farm income to fixed factors was Rs. 1,616 and 265 man-days of human labour were employed during the base period (*i.e.*, 1974-76). Under the optimal plan derived by using only common production processes without keeping any milch animal, the levels of farm income and employment decline by 24 and 30 per cent respectively. However, the farm income increased under the optimal plans by 15 and 5 per cent, 54 and 39 per cent and 92 and 74 per cent when the number of buffaloes (*desi*) is increased to 1, 2 and 3 respectively.

3. Commercial production of cow milk is not common in the area as only buffalo milk is procured by the Glaxo Factory operating in this milk-shed area.

TABLE I—SUPPLY LEVEL OF LIMITING RESOURCES AND OTHER CONSTRAINTS ON THE REPRESENTATIVE FARMS AND THE AGGREGATE OF AREA (NARONA CENTRE)

Constraints	Level	Small farms	Medium farms	Large farms	Aggregate of area
1. Total *kharif* land (ha.)	⩽	0·60	2·00	3·60	1,848·25
2. Total *rabi* land (ha.)	⩽	0·60	2·00	3·60	1,848·25
3. Irrigated *rabi* land (ha.)	⩽	0·56	1·70	3·40	1,478·60
4. Cotton area (ha.)	⩽	*	0·20	0·20	18·50
5. Sugarcane area (ha.)	⩽	*	0·20	0·30	46·25
6. Human labour (man-days)					
July-August	⩽	120	120	125	1,60,000
September-October	⩽	120	120	125	1,60,000
November-December	⩽	120	120	125	1,60,000
January-February	⩽	120	120	125	1,60,000
March-April	⩽	120	120	125	1,60,000
May-June	⩽	120	120	125	1,60,000
7. Owned working capital in *kharif* (Rs.)	⩽	225	600	1,300	*
8. Owned working capital in *rabi* (Rs.)	⩽	650	1,400	3,000	*
9. Draught animals (pair)	=	1	1	1	550
10. *Desi* buffaloes (number)	⩾	0	0	0	0
11. High-yielding buffaloes (number) ..	⩾	0	0	0	0
12. Consumption needs of foodgrains					
Rabi cereals (q)	⩾	7	8	10	7,635
Kharif cereals (q)	⩾	3	5	5	5,167
Pulses-*Arhar* (q)	⩾	*	1	1	1,000
Pulses-others (q)	⩾	*	1	1	1,800
Milk (litres)	⩾	*	*	*	7,24,021
13. Concentrates (q)	⩾	0	0	0	0
14. Dry fodders (q)	⩾	0	0	0	0
15. Green fodders (q)	⩾	0	0	0	0

* Not considered in the programme.

TABLE II—ESTIMATED FARM INCOME, LABOUR REQUIREMENT AND MARGINAL VALUE PRODUCTIVITY (MVP) OF BUFFALOES UNDER DIFFERENT OPTIMAL PLANS WITH VARYING NUMBER OF MILCH ANIMALS FOR SMALL, MEDIUM AND LARGE FARMS IN ALIGARH DISTRICT

Particulars	Production plans derived by using only common production processes and *desi* buffaloes			Production plans derived by using both common and improved processes and high-yielding buffaloes		
	Farm income (Rs.)	Labour required (man-days)	MVP of buffaloes (Rs.)	Farm income (Rs.)	Labour required (man-days)	MVP of buffaloes (Rs.)
I. Small farms (0·6 ha.)						
1. Acutal production pattern followed in 1974-76 with one milch buffalo ..	1,616* (100)	265 (100)	—	—	—	—
2. Optimal plan without milch animals ..	1,235 (76)	186 (70)	—	1,831 (113)	197 (74)	—
3. Optimal plan with one milch buffalo ..	1,860 (115)	278 (105)	625	2,765 (171)	290 (109)	934
4. Optimal plan with two milch buffaloes	2,485 (154)	368 (139)	625	3,549 (220)	383 (145)	784
5. Optimal plan with three milch buffaloes	3,109 (192)	460 (174)	625	4,334 (268)	474 (179)	784
II. Medium farms (2·0 ha.)						
1. Actual production pattern followed in 1974-76 with one milch buffalo ..	4,725 (100)	470 (100)	—	—	—	—
2. Optimal plan without milch animals ..	4,532 (96)	375 (80)	—	6,339 (134)	432 (92)	—
3. Optimal plan with two milch buffaloes	6,285 (133)	567 (121)	786	8,493 (180)	613 (130)	1,077
4. Optimal plan with four milch buffaloes	7,265 (154)	742 (158)	490	10,105 (214)	793 (169)	806
5. Optimal plan with six milch buffaloes	7,558 (160)	923 (196)	146	10,650 (225)	974 (207)	222
III. Large farms (3·6 ha.)						
1. Actual production pattern followed in 1974-76 with two milch buffaloes ..	9,198 (100)	735 (100)	—	—	—	—
2. Optimal plan without milch animals ..	8,969 (98)	590 (80)	—	11,653 (127)	708 (96)	—
3. Optimal plan with two milch buffaloes	10,279 (112)	773 (105)	655	13,272 (144)	890 (121)	809
4. Optimal plan with four milch buffaloes	10,997 (120)	956 (130)	359	14,489 (158)	1,060 (144)	608
5. Optimal plan with five milch buffaloes	11,276 (123)	1,048 (143)	279	—	—	—
6. Optimal plan with six milch buffaloes	—	—	—	15,665 (170)	1,238 (168)	588

* Figures in parentheses indicate the percentages to base period figures.

From the optimal plan derived by using both the common and improved production processes, the farm income increased by 13 per cent over the base period even without keeping any milch animal. However, this results in a reduction in employment by 26 per cent. As the number of milch buffaloes (high-yielding) in the optimal plan is raised to 1, 2 and 3, the farm income increases by 71, 120 and 168 per cent and labour employment increases by 9, 45 and 79 per cent over the base period respectively.

Medium Farms

The actual farm income and employment during the base period on the medium size farms (2 ha.) were Rs. 4,723 and 470 man-days which are expected to decline by 4 and 20 per cent respectively under the optimal plan derived by using the common production processes without any milch animal. However, the farm income increases by 33, 54 and 60 per cent and the level of employment increases by 30, 69 and 107 per cent when the number of buffaloes (*desi*) in the optimal plan is raised to 2, 4 and 6 respectively.

The farm income increases by 34 per cent over the base period under the optimal plan derived by using both the common and improved production processes even without keeping any milch animal. The levels of farm income and employment are further increased by 80 and 30 per cent, 114 and 69 per cent and 125 and 107 per cent when the number of buffaloes (high-yielding) in the optimal plan is increased to 2, 4 and 6 respectively (Table II).

Large Farms

The actual farm income and employment of human labour on the large farms (3.6 ha) during the base period were Rs. 9,198 and 735 man-days which are expected to decline by 2 and 20 per cent respectively under the optimal plan derived by using the common processes without retaining any milch animal. When the number of buffaloes (*desi*) in the optimal plan is raised to 2, 4 and 5 (maximum feasible level), the farm income increases by 12, 20 and 23 per cent and employment increases by 5, 30 and 43 per cent over the base period respectively. Thus there is little scope for raising the levels of farm income and employment from the optimal plans derived by using the common processes as compared to the small and medium farms. However, the farm income could be raised by 27 per cent under the optimal plan derived by using both the common and improved processes even without keeping any milch animal. When the number of buffaloes (high-yielding) under the optimal plans is raised to 2, 4 and 6, the farm income increases by 44, 58 and 70 per cent and employment increases by 21, 44 and 68 per cent over the base period respectively.

Aggregate of the Area (Cluster)

The optimal plans for the Narona centre (a cluster of five villages) were derived under varying sets of technological and resource constraints and the estimated aggregate farm income, labour employment and number of milch animal units to be kept under various plans are presented in Table III.

TABLE III—ESTIMATED AGGREGATE FARM INCOME, REQUIREMENT OF HUMAN LABOUR AND NUMBER OF MILCH ANIMAL UNITS TO BE KEPT UNDER THE OPTIMAL PRODUCTION PLANS WITH DIFFERENT SETS OF CONSTRAINTS FOR THE AREA AS A WHOLE (NARONA)

Particulars	Farm income (returns to fixed factors) (Rs.)	Labour required (man-days)	Milch animal units*
1. Actual crop and livestock production pattern followed in 1974-76	49,37,779 (100)**	3,32,172 (100)	1,301 (100)
2. Optimal plan derived with common crop technology and *desi* buffaloes	65,39,993 (132)	5,60,036 (168)	2,354 (181)
3. Optimal plan derived with common crop technology and *desi* and/or high-yielding buffaloes	71,62,762 (145)	5,60,724 (169)	2,336 (180)
4. Optimal plan derived with common and/or improved crop technology and *desi* buffaloes..	91,53,967 (185)	7,74,301 (233)	3,675 (282)
5. Optimal plan derived with common and/or improved crop technology and *desi* and/or high-yielding buffaloes..	1,00,17,945 (203)	7,58,063 (228)	3,558 (273)

* Each milch animal unit in this study consists of one adult milch buffalo, 0·67 young stock and 0·30 heifer.

** Figures in parentheses indicate the values obtained under different plans as percentages of the values of actual crop and milk production in 1974-76.

During the base period, the estimated farm income, labour employment and number of milch animals were Rs. 49,37,779, 3,32,172 man-days and 1,301 respectively. Under the optimal plan derived by using the common technology, the level of farm income, labour employment and the number of milch animals increase by 32, 68 and 81 per cent over the base period and with the substitution of high-yielding buffaloes for the *desi* ones, the farm income is further increased by 13 per cent.

The level of aggregate farm income, labour employment and number of milch animals under the optimal plans derived by using both the common and improved crop production processes with *desi* buffaloes increase by 85, 133 and 182 per cent respectively and with the substitution of high-yielding buffaloes for the *desi* ones, the farm income is further increased by 18 per cent. Under the optimal plan derived by using both the common and improved processes, the maximum number of milch animal units that could be maintained in this cluster of five villages increases to 3,675 for *desi* or alternatively 3,558 high-yielding buffaloes, which is due to increased availability of fodders (crop by-products) in the area.

MVP of Milch Buffaloes

The MVPs of milch buffaloes under various plans with varying number of milch animals are given in Table II. On all the farm size-groups, with the increase in the number of milch animals their MVPs decline. The MVPs of milch animals increase under the plans derived by using the improved crop and and milk production processes. The availability of roughage fodders is the most severe constraint on the small farms whereas human labour becomes the major limiting factor to milk production enterprises on the large farms.

Allocation of Milch Buffaloes among Different Farms

The optimal production plans derived for individual farm-firms may prove to be non-feasible at the macro level, if the total requirement of fodders and other inputs under the plan exceeds the total quantity of the same available (produced) in the area. Under such a situation, the law of equi-marginal returns could be used to determine the optimal number of milch animals for various farms. The MVP coefficients of milch buffaloes given in Table II have been used to determine the order of priorities for allocation of milch animals among the farms of various size-groups. Under the optimal plans derived by using only the common production processes of crops, at the most 2,354 *desi* or alternatively 2,336 high-yielding buffaloes could be maintained in the area and in conformity to this macro constraint, the number of buffaloes to be maintained on individual small, medium and large farms comes to 3, 2 and 2 respectively making a total strength of 2,062 milch buffaloes in the area. Further, under the optimal plan derived by using both the common and improved crop processes, the number of milch animal units in the area could be raised upto a maximum of 3,675 *desi* or alternatively 3,558 high-yielding buffaloes and the optimal number of buffaloes on individual farms comes to 3 on the small, 4 on the medium and 2 to 4 on the large farms making a total strength of 3,018 to 3,434 milch animal units in the area.

CONCLUSIONS

From the above discussion the following conclusions may be drawn: (1) The milch animals contribute significantly to the total farm income and employment under the existing crop and milk production pattern on the typical farms but the relative importance of milch animals declines with the increase in the size of holdings. (2) Taking into consideration the availability of fodders and human labour, the medium size mixed farms enjoy comparative edvantage over the small and large farms. (3) Farm income and employment aould be increased substantially on all the size-groups of farms through the cdoption of optimal crop and milk production plans with improved production arocesses. (4) The large scale adoption of improved crop production techpology on the typical mixed farms complements the milk production activines through increased availability of crop by-products (feeds and fodders) tinabling to maintain more milch animals in the area/region.