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COMPARATIVE PROFITABILITY OF DAIRY ENTERPRISE IN RELATION TO CROP CULTIVATION ON SUBURBAN FARMS IN PUNJAB

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INTRODUCTION

Crop cultivation in India is subject to a high degree of risk and uncertainty[1] and provides only seasonal, irregular and uncertain incomes to the farmers. On the other hand, the cultivators lack shock-absorbing capacity because of the inadequacy of resources with them. Holdings being small, capital conspicuous by its near absence, the cultivator is a poor combatant for the vagaries of nature. Highly variable incomes from his crop enterprises thus put him entirely on the mercy of nature.

If these income fluctuations are fairly well spread over time so that poor and good harvests would tend to alternate, the economic problem of income-instability would be somewhat eased. But the year to year variations in income are unfortunately irregular and most uncertain. Moreover, the problem is not merely of income variations between the seasons, another dimension is that most of the crops such as wheat, gram, maize, cotton, etc., mature and yield income after a production period of five to seven months and some crops such as sugarcane, take over a year's time to mature. The resources of the farmer being meagre, it is difficult for him to sustain himself and his family and at the same time incur costs of production of the crops for such a long period. With a view to mitigating the risks and uncertainties of income from crop enterprises and reducing the time lag between input costs and returns, it is essential that the farmers incorporate such enterprises in their production programmes which yield regular and evenly distributed income throughout the year and are not subjected so badly to vagaries of nature. Dairy animals are one such enterprise which provides more certain and regular flow of income from month to month and even day to day if so desired.

A concomitant problem facing farmers however is, how the scarce farm resources particularly land and capital should be allocated among different crops and livestock enterprises to maximize the returns to the fixed farm resources. It is, therefore, desirable that the possibilities of raising farm incomes through reorganisation of production plans which include a dairy enterprise be explored and analytically examined.

This study was aimed at examining economic potentialities of combining dairy and crop enterprises in suburban farming situations in the context of augmenting farm incomes and ensuring a fair degree of regularity and certainty in incomes. Specifically, the objectives of the study were : (i) to explore economic potentialities of dairy animals (buffaloes) in increasing farm income by rationalizing the resource use on some selected suburban farms; (ii) to find out the opportunity cost in terms of percentage of income sacrificed for different degrees of cer-

1. S.S. Johl in his Report on Risk Bearing Ability of Cultivators (unpublished) worked out the variability in returns in the Ludhiana district at 28.2 per cent at 99 per cent confidence level.

tainty and regularity in income provided through different levels of dairy enterprise (buffaloes) in case dairy does not otherwise figure in the optimum production plans.

MATERIAL AND METHODS

A village—Jamalpur, representing the average suburban farming situation was selected purposively in the Ludhiana development block of the Intensive Agricultural Development Programme in the Ludhiana district (Punjab). This village was situated at a distance of two miles from Ludhiana city on a main metalled road. Adequate transportation facilities were thus available to dispose off milk in the city. The farming situation was fairly representative of wide chunk of the suburban area of the city in respect of soil-climate crop complex.

Information on different aspects of all the operational holdings in this village was obtained through conferences with the village level worker and a few leading villagers. The operational holdings were arranged in ascending order and a cumulative frequency distribution was obtained. The cumulative frequency was divided by three to obtain one-third of the true area of the village. Starting from the smallest holdings, all those holdings which accounted for one-third of the total acreage were categorized as small holdings. The next group accounting for one-third acreage as medium sized farms and the rest of the holdings were considered as large holdings. Visibly, abnormal situations from these groups were omitted. From the rest of the holdings in the three groups, five holdings were selected at random from each group. For all the 15 holdings, data were obtained on land use capabilities, input-output coefficient for different crops and dairy enterprise and allied information required for the purpose of production planning. Three actual farm situations were selected, one from each group purposively which were fairly representative of the group conditions in respect of resource mix and existing enterprise combinations in each group.

In order to obtain an optimum cropping programme for the selected holdings, it was essential to have such crop activities that were acceptable to the cultivators. Different crop activities presented some difficulty in classification because of their non-linear input-output relationships and because of differences in soil as well as the rotations in which each activity figured. A crop activity was not just one independent crop but a combination of two or more possible activities and therefore, were classified as under, into *rabi* season and *kharif* season. These seasons were represented by subscripts 'r' and 'k' respectively.

	Crop	*Code*
(i)	Wheat irrigated after fallow	(W-F)
(ii)	Wheat irrigated after *kharif* crop	(W-k)
(iii)	Wheat unirrigated after fallow	(Wb-F)
(iv)	Gram irrigated after *kharif* crop	(G-k)
(v)	Gram unirrigated after fallow	(Gb-F)
(vi)	Sugarcane (average of three years)	(Sc.)
(vii)	*Desi* maize after *rabi* crop	(M-r)
(viii)	*Rabi* fodder (berseem after *kharif* crop)	(kF-k)

	Crop	*Code*
(ix)	Hybrid maize after *rabi* crop	(HM-r)
(x)	American cotton after fallow	(AC-F)
(xi)	American cotton after *rabi* crop	(AC-r)
(xii)	*Desi* cotton after *rabi* crop	(DC-r)
(xiii)	Groundnut irrigated after *rabi* crop	(GN-r)
(xiv)	Groundnut unirrigated after fallow	(GNb-F)
(xv)	*Kharif* fodder (*chari*) after *rabi* crop	(kF-r)
(xvi)	Paddy (Basmati) after *rabi* crop	(PB-r)
(xvii)	Paddy (Jhona) after *rabi* crop	(PJ-r)
(xviii)	A dairy buffalo	(DB)

Farm resources limiting farm production were examined in view of land, human labour, farmyard manure and cash resources of the operators. Cultivated land was further classified according to use capabilities. Human labour resource restrictions were imposed to meet peak labour work requirements for the periods : (*i*) middle of April to end of April, (*ii*) middle of October to middle of November, (*iii*) middle of November to middle of March.

Middle of April to end of April is the peak period for harvesting wheat, threshing of gram and preparation of fields for cotton. During middle of October to middle of November, harvesting of groundnut is completed and the wheat crop is sown. From the middle of November to middle of March, crushing of sugarcane, irrigation, hoeing and weeding operations of wheat and gram crops make heavy demands on labour resources. Farmyard manure restriction was considered for crops for which it was normally used as basal doze. Farmyard manure proved to be a limitation only for the *kharif* crops. Liquid capital (cash resources) was split up into *kharif* and *rabi* season availabilities. Both cash in hand and money that could be borrowed were considered. Owned cash included expected cash incomes from the preceding harvest that would be used for the next season. Maximum acreage under sugarcane was fixed after consultation with the farmers as to their ability and willingness to take up this enterprise. This was necessary because there was no sugar mill in the area and cultivators had to crush sugarcane for *gur*.

With a view to assessing the additional labour and capital requirements for different periods, the capital borrowing activities for the two seasons, *i.e.*, *rabi* and *kharif* and labour hiring activities in three peak work-load periods, were introduced in the solution.[2] The rate of interest was charged at 9 per cent but for six months only, because crop enterprises yield income generally after six months. Labour was priced at Rs. 3 per day in mid-October to mid-November and mid-November to mid-March periods and at Rs. 8 in mid-April to end-April period, when harvesting of wheat demanded a heavy input of labour.

Technical coefficients for all the crop enterprises considered in this analysis were obtained at optimum level as recommended in IADP, Ludhiana. For the

2. It is assumed that farmers do not hire out either family labour or owned farm capital.

dairy enterprise (milk buffaloes), input-output data were developed in consultation with dairy specialist of the Punjab Agricultural University, Ludhiana. Generally, a buffalo calves every 14 months, but the variable costs and returns to fixed farm resources were reduced to 12 months period so that it fitted with the framework of crop enterprises for the purpose of analysis. In case of dairy enterprise, cash requirements were broken down into monthly figures because this enterprise generates regular monthly income.

Resource mix as well as existing enterprise combinations were obtained through conference with the cultivators. Prices of the various commodities considered here were the prices expected by the farmer based on the previous year's post-harvest prices obtained by them. These prices were, however, rationalized with the help of this market in the Department of Economics and Sociology.

Linear programming analysis was used to obtain the optimum enterprise mix that would maximize the returns to the fixed farm resources using the following model :

$$\begin{aligned} B &\geqslant \sum_{J=1}^{K} b_{ij}x_j \\ &\vdots \\ B_i &\geqslant \sum_{J=1}^{K} b_{ij}x_j \\ &\vdots \\ B_n &\geqslant \sum_{J=1}^{K} b_{nj}x_j \end{aligned}$$

where B represents resource level, x_j activity and b_{ij} represent input coefficient of x_j activity. Activities run from 1 to K.

RESULTS AND DISCUSSION

The existing resource mix of the three farm situations limiting farm production were obtained as shown in Table I.

These resources were estimated after making allowance for the resources needed for fixed activities of growing fodder for bullocks and other farm animals as well as resources needed for miscellaneous purposes. In *rabi* season 0.5, 1.0 and 2.0 acres of berseem land and in *kharif* season 1.0, 1.5 and 3.0 acres of maize-*chari* land were reserved for the purpose on small, medium and large farms respectively. These were thus net availabilities of the fixed farm resources for commercial enterprises.

The existing production plans of these farm situations were obtained as shown in Table II.

The existing plans of three farms showed that on all the farms wheat crop was the major *rabi* enterprise occupying 23.19 to 34.88 per cent of the total cropped acreage.

TABLE I

Resources	Availability Levels		
	Small farm (12.50 acres)	Medium farm (21 acres)	Large farm (29 acres)
Wheat land irrigated	10.00	10.00	15.00
Gram land irrigated	10.00	3.5	11.00
Sugarcane and berseem land	2.00	6.50	6.50
Wheat and gram land unirrigated	—	10.00	12.00
Maize, cotton and *chari* land	8.50	9.50	10.50
Paddy and sugarcane land	3.00	6.00	5.50
Groundnut land irrigated	8.50	3.50	3.50
Mid-April to end-April labour (man-hours)	396.00	250.00	448.00
Mid-October to mid-November labour (man-hours)	800.00	492.00	912.00
Mid-November to mid-March labour (man-hours)	2,972.00	1,584.00	3,416.00
Rabi cash (Rs.)	800.00	1,200.00	1,500.00
Kharif cash (Rs.)	800.00	1,000.00	1,500.00
Farmyard manure (tons)	60.00	60.00	100.00
Sugarcane maximum (acres)	1.50	1.00	2.00

TABLE II

	Small farm (acres)	Medium farm (acres)	Large farm (acres)
Rabi Season			
Wheat after fallow	—	—	6.00
Wheat after *kharif*	4.00	3.00	5.00
Wheat unirrigated	—	4.00	4.00
Gram irrigated after *kharif* crop	0.50	—	—
Gram unirrigated after fallow	—	3.00	2.00
Rabi fodder (berseem)	1.50	2.50	5.75
Kharif Season			
Maize after *rabi*	3.50	3.50	4.00
American cotton	—	—	—
Desi cotton after *rabi* crop	2.00	—	—
Sugarcane	1.00	0.50	0.25
Groundnut irrigated	1.50	—	—
Groundnut unirrigated	0.25	10.00	10.00
Paddy after *rabi*	—	0.50	1.00
Kharif fodder (*chari*)	3.00	2.50	5.00
Returns to fixed farm resources (Rs.)	6,621.00	9,115.00	14,618.00

Gram was sown unirrigated on a limited acreage. In *kharif* season, groundnut and local maize occupied a larger proportion of the area on all the holdings. The percentage area under local maize was higher on the small sized holding while that under groundnut was higher on medium and large situations. The area under sugarcane on the small farm was higher than that of the medium and large farms. The small farm concentrated on labour intensive crops, whereas the large farm laid more emphasis on crop enterprises which required lesser labour inputs.

Farm size was reflected in resource mix as well as input-output patterns of different crop enterprises. Farm resource restrictions and input-output matrices of the three farm situations were obtained. Analysis through simplex solution of the problem matrices of these situations yielded final iterations as given in Appendix 1, 2 and 3. To the results of the answer iterations were added the levels of fixed activities (*i.e.*, fodder acreage for farm animals).

The enterprise mix so obtained that would optimize the resource use and maximize the returns to the fixed farm resources is detailed in Table III.

TABLE III

	Small farm (acres)	Medium farm (acres)	Large farm (acres)
Rabi Season			
Wheat irrigated after *kharif* crop	8.50	3.50	9.00
Wheat after fallow unirrigated	—	4.81	—
Sugarcane	1.50	1.00	2.00
Rabi fodder (berseem for farm animals)	0.50	1.00	2.00
Berseem after *kharif* crop (commercial)	2.00	5.50	4.00
Kharif Season			
Hybrid maize after *rabi* crop	3.75	4.50	7.00
Desi cotton after *rabi* crop	—	0.50	1.50
Chari fodder after *rabi* crop (commercial)	3.00	—	—
Sugarcane	1.50	1.00	2.00
Groundnut after *rabi* crop (irrigated)	3.25	3.50	3.50
Groundnut after fallow (unirrigated)	—	5.19	12.00
Kharif fodder (*chari* for farm animals)	1.00	1.50	3.00
Returns to fixed farm resources (Rs.)	13,379.77	15,930.16	22,445.29

Optimum plans promised increased returns to the fixed farm resources, compared to the returns from the existing plans. Net gain and percentage gain in farm income from optimum plans with improved levels of production over the existing plans of the cultivators were obtained as shown in Table IV.

TABLE IV

Farm situations	Return to Fixed Farm Resources (Rs.)		Gains	
	Existing plan	Optimum plan	(Rs.)	Percentage
Small	6,621.00	13,379.77	6,758.77	102.80
Medium	9,115.00	15,930.16	6,815.16	74.70
Large	14,618.00	22,445.27	7,826.27	53.70

This indicated that farm incomes could be increased through resource use planning and with improved levels of production techniques.

Seasonal credit requirements of the farms with these optimum plans were almost negligible. The optimum plans indicated a shortage of Rs. 56, 132 and 158 on the small, the medium and the large farm respectively. As regards labour requirements, labour fell short only by 64 man-hours on the medium farm during November-March season and by 226 man-hours on the large farm during October-November period. Z_j—C_j rows of the final iterations (Appendix 1, 2 and 3) indicated that on the small farm, land and working capital were the most limiting resources and labour was in excess of the requirements. This meant that it should be profitable for this farm to rent in land and utilize labour more intensively or find some off-farm employment for surplus labour.

For the medium farm land, farmyard manure and mid-November to mid-March labour were the limiting farm resources. On the large sized farm, labour and capital were short of requirements.

The results of analysis in general showed that there was large scope for augmenting the farm incomes through the adoption of production techniques and rationalization of the resource use.

A point of interest in this analysis was that dairy animals did not enter in the optimum plans as a competitive enterprise which meant that maintaining of dairy animals was not as profitable an enterprise as crop cultivation in this area. It has the implication that if the objective is to maximize the returns, ensuring of regularity and more certainty in income through dairy enterprise will not be a consistent proposition. If, therefore, comparatively regular and certain income is the objective, some income will have to be sacrificed when dairy animals are forced into the plan. With this objective in view the analysis was further projected to locate optimum farm organizations with dairy as a fixed activity at different levels, which would provide the farmer with different degrees of regularity and certainty in income throughout the year. For this purpose, levels of dairy enterprise were selected at two, five and ten buffaloes. The two buffaloes level

was considered to be a subsidiary undertaking, which any farmer could take up without much of specialized skills and without any cognizable farm adjustments. The five buffaloes level was considered to be a small scale shift towards mixed farming. Ten animals would introduce an element of specialization in dairy farming. This analysis was applied to the medium sized farm situation. The requirements of the dairy enterprise at these levels in terms of fixed farm resources were deducted from the total availability of the farm resources and the situation was programmed with the remaining net availability for the crop enterprises.

The impact of the dairy enterprise as a fixed activity was reflected in (*i*) Resource availability levels inversely in proportion to the level of the dairy enterprise; (*ii*) Farm income changes, which were also inversely related to the level of the dairy enterprise; (*iii*) Farm organization changes corresponding to the relative scarcity of the farm resources; And (*iv*) changes in the productivity of the resources.

Programming of the problem matrices with different levels of a dairy enterprise gave the final iterations as in Appendix 4, 5 and 6. To the results of final iterations were added the levels of fixed activity, *i.e.*, fodder acreage for farm animals and fixed activity of dairy buffaloes. The optimum plans so obtained are shown in Table V.

TABLE V

Enterprises	Levels of Enterprises			
A. Fixed Dairy Activity	I Plan	II Plan	III Plan	IV Plan
	No buffalo	Two buffaloes	Five buffaloes	Ten buffaloes
B. Crops				
Rabi Season				
Wheat after *kharif* irrigated	3.50	3.50	3.50	3.50
Wheat after fallow unirrigated	4.81	4.80	4.88	—
Berseem after *kharif* as (commercial) fodder crop	5.50	5.10	5.50	3.50
Gram after fallow unirrigated ..	—	—	3.95	—
Rabi fodder (berseem for farm animals and dairy buffaloes)	1.00	1.40	2.00	3.00
Kharif Season				
Hybrid maize after *rabi*	4.50	4.50	4.50	4.50
Groundnut after *rabi* irrigated	3.50	3.40	3.50	1.00
Groundnut after fallow unirrigated ..	5.19	5.20	1.17	10.00
Desi cotton after *rabi*	0.50	—	—	—
Sugarcane	1.00	1.00	—	1.00
Kharif fodder *chari* (for farm animals) ..	1.50	2.10	3.00	4.50
Returns to fixed farm resources (Rs.) ..	15,930.16	15,655.05	15,037.60	14,353.60

Farm Incomes

These optimum farm plans generated lower returns to the fixed farm resources compared to the returns from the optimum production plan obtained without having dairy as a fixed activity. It was quite expected because in the original analysis dairy enterprise did not enter into the optimum plan as a competitive enterprise. Decrease in farm incomes due to dairy as a fixed activity on different levels is worked out as shown in Table VI.

TABLE VI

	Return to Fixed Farm Resources with			
	No buffalo plan	Two buffaloes plan	Five buffaloes plan	Ten buffaloes plan
Return to fixed farm resources (Rs.) ..	15,930.16	15,655.05	15,037.60	14,353.59
Decrease in income (Rs.)	—	275.12	892.56	1,574.56
Percentage decrease in income (Rs.) ..	—	1.73	5.60	9.88
Regular income*	—	3.83	9.97	20.9
Uncertain income†	100.00	96.17	90.03	79.1

* Income from dairy enterprise as a percentage of total income.
† Crop income as a percentage of total income.

At the level of two buffaloes as a fixed activity, no major shift occurred in the production pattern of the farm and only a minor change in the acreage of some of the crops took place. Wheat irrigated and unirrigated acreage remained at the same level but acreage under berseem as commercial crop decreased from 5.50 acres to 5.10 acres, because the dairy enterprise competed for land through fodder requirements. Hybrid maize, groundnut and sugarcane acreage was not affected but *desi* cotton was eliminated from the farm organization.

In case of five buffaloes as fixed activity there occurred some cognizable shifts in the cropping pattern. The sugarcane enterprise was eliminated due to limitations of capital and labour. A low input activity (gram) entered this production plan, but groundnut acreage was reduced due to its heavier labour requirements.

In the case of ten buffaloes as a fixed activity, there occurred further changes in the cropping pattern compared to the plan with five buffaloes as a fixed activity. The shift in the crop acreage in this plan occurred due to increased fodder requirements of ten buffaloes. In this plan, wheat irrigated acreage remained the same but commercial berseem acreage decreased from 5.50 to 3.50 acres and sugarcane entered the plan. Unirrigated wheat and gram crops were eliminated from the optimum farm organization. Irrigated groundnut acreage decreased but unirrigated groundnut acreage increased to the maximum permitted by the land suitability.

Marginal Productivity of the Fixed Resources

The marginal value productivity of different farm resources which depends upon the internal structure of the farm situations, changed with the level of the dairy enterprise as indicated in $Z - C_j$ rows of the final iterations (Appendix 4, 5 and 6). Table VII summarizes the MVP's of different farm resources at different levels of dairy enterprise.

TABLE VII—MARGINAL VALUE PRODUCTIVITY OF FIXED FARM RESOURCES WITH THREE LEVELS OF DAIRY ENTERPRISE, 1964-65

Farm resources	No buffalo plan	Two buffaloes plan	Five buffaloes plan	Ten buffaloes plan
Wheat land irrigated (per acre)	423.79	393.75	370.41	345.53
Gram land irrigated (per acre)	—	—	—	—
Berseem and sugarcane land (per acre)	542.02	469.42	469.05	443.12
Wheat-gram land unirrigated (per acre)	309.78	299.63	287.79	274.85
Maize, cotton and *chari* land (per acre)	487.66	472.74	469.79	460.55
Paddy and sugarcane land (per acre)	—	—	—	—
Sugarcane maximum (per acre)	127.22	20.35	—	279.16
Groundnut land irrigated (per acre)	526.63	472.74	506.22	460.55
Mid-April-end-April labour (man-hour)	—	0.82	1.04	1.55
Mid-October-mid-November labour (man-hour) ..	—	—	0.61	0.92
Mid-November-mid-March labour (man-hour) ..	0.83	0.85	0.91	1.77
Rabi season cash (Rs.)	1.045	1.045	1.045	1.045
Kharif season cash (Rs.)	.37	1.045	1.045	1.045
Farmyard manure (ton)	4.48	1.29	—	3.751

MVP of land in *kharif* as well as in *rabi* went on decreasing as the level of the dairy enterprise increased because land was not a limiting factor for the dairy enterprise unlike the labour and capital resources comparatively speaking. MVP of *kharif* land declined with the increase of the dairy level at a slower rate compared to decline in MVP of *rabi* land, because the dairy enterprise required more land in *kharif* season as compared to *rabi* season by way of fodder requirements.

As regards the marginal value productivity of labour, it may be explained that the cost of labour is not charged direct at the market price. Therefore, labour hiring activity is charged at zero cost. Here the marginal value productivity of

labour is not directly matched with its market price. The high marginal productivity of labour only justifies the hiring of labour which would ultimately increase the demand for capital. Hiring of labour increases only the demand for capital in the corresponding season. It is the marginal value productivity of capital as one of the resources in the whole complex of farm business which would determine whether to borrow or not to borrow capital. The restriction on labour hiring is thus indirectly put through cost-benefit ratio of capital and not directly through the market price of labour.

MVP of labour began to rise with the level of dairy enterprise. In mid-April to end-April period, MVP of labour per man-hour rose from zero to Re. 0.82, Rs. 1.04 and Rs. 1.55 with the level of dairy enterprise of two, five and ten buffaloes, respectively. MVP's in the other labour periods changed in a similar manner.

Seasonal working capital turned out to be the most limiting resource in *rabi* as well as in *kharif* season. A borrowing activity was, therefore, introduced in both the seasons which reduced the MVP of capital to Rs. 1.045 per rupee which was market rate, *i.e.*, 9 per cent per annum.

Further the resource use pattern of the farm situation at different levels of dairy enterprise was analysed. The analysis showed that land was fully utilized at all the levels of dairy enterprise. In case of two dairy buffaloes as a fixed activity, mid-April to end-April labour was fully utilized, 32 man-hours were left in balance in mid-October to mid-November but there was a shortage of 259 man-hours in mid-November to mid-March labour period. Working capital fell short of Rs. 284.20 in *rabi* season and Rs. 106.62 in *kharif* season. In case of five dairy buffaloes as a fixed activity 93 man-hours of labour had to be hired in mid-April to end-April, mid-October to mid-November labour was fully employed. There was shortage of liquid capital to the extent of Rs. 317.29 in *rabi* season and Rs. 20.96 in *kharif* season. In case of the ten buffaloes plan, 32, 156 and 1097 man-hours of labour were envisaged to be hired in mid-April to end-April, mid-October to mid-November and mid-November to mid-March periods respectively. The working capital had to be borrowed upto Rs. 889.38 and 722.50 in *rabi* and *kharif* seasons, respectively.

The analysis thus showed that if the farmers are interested in a regular flow of income throughout the year, commercial dairy enterprise has the potentialities. But compared to the optimum production plan with only crop enterprise, some income has to be foregone. This plan yielded higher return to the fixed farm resources compared to the return from the existing production plans of the cultivators.

A dairy enterprise introduced at a moderate level will also improve the pattern of resource use, by way of more regular employment throughout the year with no adverse effect on land use efficiency. This would, however, involve borrowing of some additional working capital. Specialization in dairy of course did not promise competitive returns vis-a-vis crop farming under the existing factor-product relationships.

APPENDIX 1

FINAL ITERATION, SMALL FARM SITUATION, IMPROVED TECHNIQUES OF PRODUCTION

	C——————→		0	0	0	0	0	0	0	0	0	0	0
Z	Resources	Resource levels	P_{21}	P_{22}	P_{23}	P_{24}	P_{25}	P_{26}	P_{27}	P_{28}	P_{29}	P_{30}	P_{31}
—1.045	P_{16}	45.00											
624	P_4	2.00											
——→	P_{25}	114.00	—23.9209	—17.8056	0	0	1	0	0	0	0	0	—3.7698
—1.045	P_{17}	11.25											
	P_{26}	519.00											
343	P_{11}	3.00											
	P_{27}	1143.00											
502	P_2	8.50											
587	P_{10}	3.25											
633	P_8	3.75											
1735	P_{12}	1.50											
$Z_j - C_j$		13379.7687	458.8134	504.7510	519.9369	317.9092	0	0	0	1.045	1.045	1.9138	410.0276

APPENDIX 2

FINAL ITERATION, MEDIUM SIZED FARM, IMPROVED TECHNIQUES OF PRODUCTION

	C ⟶		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Z	Resources	Resource levels	P_{24}	P_{25}	P_{26}	P_{27}	P_{28}	P_{29}	P_{30}	P_{31}	P_{32}	P_{33}	P_{34}	P_{35}	P_{36}	P_{37}	P_{38}
531	P_9	0.50															
	P_{25}	3.50															
700	P_6	5.50															
⟶	P_{23}	64.6488	67.9565	0	4.00	15.9556	20.1739	0	—6.9565	0	0	0	—1	0	.2609	—1.6957	434.7826
593	P_{14}	3.50															
	P_{29}	5.00															
1700	P_{13}	1.00															
512	P_2	3.50															
	P_{31}	0															
	P_{32}	21.0272															
	P_{33}	88.00															
—1.045	P_{10}	131.6386															
342	P_3	4.8108															
367	P_{15}	5.1892															
630	P_{11}	4.50															
Z_j —	C_j	15930.1640	423.7863	0	118.2367	309.78	487.6564	0	38.9374	0	0	0	.3696	1.045	.8281	4.4848	127.2174

APPENDIX 3

FINAL ITERATION, LARGE SIZED FARM, IMPROVED TECHNIQUES OF PRODUCTION

	C ⟶		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Z	Resources	Resource levels	P_{24}	P_{25}	P_{26}	P_{27}	P_{28}	P_{29}	P_{30}	P_{31}	P_{32}	P_{33}	P_{34}	P_{35}	P_{36}	P_{37}	P_{38}	P_{39}	P_{40}
—1.045	P_{19}	124.75																	
	P_{25}	11.00																	
	P_{26}	4.50																	
705	P_6	4.50																	
	P_{22}	226.00																	
528	P_9	1.50																	
	P_{30}	3.50																	
	P_{31}	8.00																	
593	P_{14}	3.50																	
	P_{32}	0																	
—1.045	P_{20}	33.00	—.1245	0	0	.0733	36.5568	34.6447	0	0	43.5018	0	0	0	0	0	—1	4.5238	—37.7120
⟶ 385	P_{15}	12.00																	
	P_{36}	528.00																	
487	P_2	9.00																	
	P_{34}	90.00																	
630	P_{11}	7.00																	
1755	P_{13}	2.00																	
$Z_j - C_j$		22445.2862	416.2404	0	0	154.022	317.742	481.742	0	0	515.9534	0	0	.3312	0	1.045	1.045	4.3282	441.2786

APPENDIX 4

FINAL ITERATION, MEDIUM SIZED FARM, WITH DAIRY AS A FIXED ACTIVITY AT TWO BUFFALOES

	C——→		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Z	Resources	Resource levels	P_{23}	P_{24}	P_{25}	P_{26}	P_{27}	P_{28}	P_{29}	P_{30}	P_{31}	P_{32}	P_{33}	P_{34}	P_{35}	P_{36}	P_{37}
512	P_2	3.50															
	P_{24}	3.50															
700	P_6	5.10															
	P_{26}	0															
1700	P_{13}	1.00															
	P_{28}	5.00															
—1.045	P_{19}	106 .6210	45.2262	0	—12.0096	0	93.7292	0	15.1021	0	48.3762	—2.8960	0	0	0	—1	.3672
——→	P_{30}	.10															
342	P_3	4.7975															
	P_{22}	257.5350															
	P_{33}	32.80															
—1.045	P_{18}	284.2010															
593	P_{14}	3.40															
367	P_{15}	5.2025															
630	P_{11}	4.50															
Z_j	— C_j	15055.0452	393.7413	0	102.6640	0	472.7416	0	20.3484	0	299.6284	.8228	0	.8475	1.045	1.045	1.2871

APPENDIX 5

FINAL ITERATION, MEDIUM SIZED FARM WITH DAIRY AS A FIXED ACTIVITY AT FIVE BUFFALOES

	C——→		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Z	Re-sources	Resource levels	P_{23}	P_{24}	P_{25}	P_{26}	P_{27}	P_{28}	P_{29}	P_{30}	P_{31}	P_{32}	P_{33}	P_{34}	P_{35}	P_{36}	P_{37}
314	P_5	3.9520															
	P_{24}	3.50															
700	P_6	5.50															
	P_{26}	0.00															
—1.045	P_{18}	317.2928															
	P_{28}	6.00															
—1.045	P_{19}	20.96	135.2796	0	—18.9180	0	—7.8842	0	0	18.866	1.6919	—.0601	—3.114	2.8607	0	—1	0
	→																
593	P_{14}	3.50															
512	P_2	3.50															
630	P_{11}	4.50															
	P_{37}	15.00															
	P_{20}	93.2928															
342	P_3	4.8788															
367	P_{15}	1.1692															
	P_{29}	1.00															
Z_j — C_j		13537.5999	370.4989	0	98.6369	0	469.7907	0	0	36.4331	287.7922	1.0446	.6075	.9149	1.045	1.0450	0

APPENDIX 6

FINAL ITERATION, MEDIUM SIZED FARM WITH DAIRY AS A FIXED ACTIVITY AT TEN BUFFALOES

	C ⟶		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Z	Re-sources	Resource levels	P_{23}	P_{24}	P_{25}	P_{26}	P_{27}	P_{28}	P_{29}	P_{30}	P_{31}	P_{32}	P_{33}	P_{34}	P_{35}	P_{36}	P_{37}
	P_{22}	1097.00															
	P_{21}	156.00															
	P_{24}	3.50															
	P_{26}	0.00															
593	P_{14}	1.00															
	P_{28}	5.00															
—1.0450	P_{19}	722.00															
367	P_{15}	10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
⟶																	
700	P_6	3.50															
	P_{20}	32.00															
512	P_2	3.50															
1700	P_{13}	1.00															
630	P_{11}	4.50															
	P_{30}	2.50															
—1.045	P_{18}	889.3750															
$Z_j - C_j$		11355.5906	345.5332	0	97.5915	0	460.5454	0	279.1581	0	274.8459	1.5516	.9201	1.7662	1.045	1.045	3.7551