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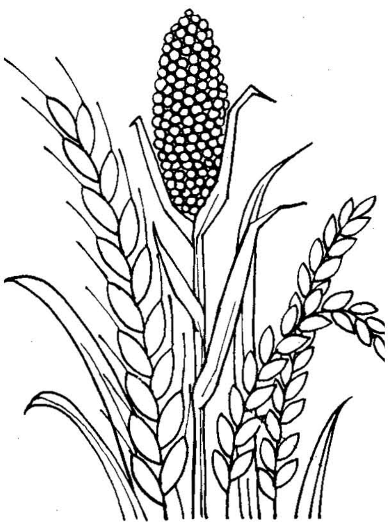

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ENTERPRISE SYSTEM FOR STABILITY AND GROWTH ON DROUGHT-PRONE FARMS: AN APPLICATION OF PARAMETRIC LINEAR PROGRAMMING

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Owing to mostly low, erratic and uncertain rainfall crop yields in drought-prone areas are not only low but highly variable. Further, wide fluctuations in product prices are also common (11).† These two factors together have made farm returns low and uncertain. Maximizing farm returns under these situations by suggesting an efficient[1] enterprise system is considered as one of the important ways to enhance the development prospects of the region. The main objective of the present study is therefore to work out efficient sets of farm plans for a representative small and large farm[2] in Bijapur district, a typical drought-prone tract of Karnataka State, India. The following hypotheses regarding resource use, net returns and mixed farming are tested in this study:

(*a*) Farmers in drought-prone areas are not efficient in resource use and they do not take advantage of the better crop varieties.

(*b*) Increased use of inputs like credit and bullock labour will not only increase net returns but add to some instability.

And (*c*) mixed farming can not only increase net returns but can add stability to it.

METHODOLOGY

Profit maximizing Linear Programming (LP) based on the data of representative farms has been frequently used for finding optimum use of farm resources. However, given that the risk attached to profit outcomes affects farmer's decision-making, some method of incorporating risk considerations into some analytical framework is desirable for farm management research and extension purposes. Quadratic programming (QP) has been suggested as the most useful tool to consider risk in farm planning. Scarcity of computer time and code and some other limitations of QP itself necessitates

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† Figures in brackets indicate reference numbers.

1. Efficient means optimal with risk minimization.

2. Analysis was confined only to a small and large farm on heavy soils for want of time and funds. It should be noted here that heavy and light soils are the two major soil types in this area. About two-thirds of the area is considered to be of heavy soil type where crops are generally taken during *rabi* (September to February) season.

a linear rather than a QP approach.[3] Minimization of total absolute deviation (MOTAD) programming (hereinafter referred to as PLP) which is a linear and an efficient (1, 3, 7 and 15) alternative to QP has aroused some research interest in recent times[4] and is applied here to a representative small and large farm in Bijapur, India.

The Model

In situations of risk, the individual drought-prone farmer is assumed to be averse to risk, so that his objective function is defined by the dual criteria of maximizing net returns and minimizing the variance (or some other measure of risk) of net returns. In our model, which is the same as MOTAD (6) model, the net return mean absolute deviations are minimized subject to expected total net return levels[5] (which are parameterised) and other resource constraints.

For parametric linear programming (PLP) the objective function is as follows:

$$\text{Min. } A = \frac{1}{s} \sum_{h=1}^{s} \left| \sum_{j=1}^{n} (C_{hj} - g_j)\, x_j \right|$$

In words, we minimize the mean absolute deviation (A), defined as the mean over (h = 1.........s) years, of the sum of the deviations of net returns (C_{hj}) from the sample mean net return (g_j), multiplied by activity levels x_j (j=1...........n). This is minimized subject to the following constraints:

$$\sum_{j=1}^{n} g_j x_j = \lambda \quad (\lambda = 0 \text{ to some maximum level}) \qquad \ldots\ldots(1)$$

such that the net return, the sum of the activity levels times their expected net returns (g_j) equals λ, a parameter to be parameterised to the maximum level of net return, and

$$\sum_{j=1}^{n} a_{ij}\, x_j \leqslant b_i \quad (\text{for all } i,\ i = 1, \ldots\ldots\ldots m) \qquad \ldots\ldots(2)$$

total activity requirements for the ith constraint, the sum of the unit activity requirements 'a_{ij}' for the constraint 'i' times the activity levels 'x_j', do not exceed the level of the ith constraint 'b_i' for all 'i' and

$$x_j \geqslant 0, \text{ all activity levels are non-negative} \qquad \ldots\ldots(3)$$

In our model, the farmer decides between possible crop combinations on the basis of expected net returns and the absolute deviation of net returns for each crop from its expected value. This is made possible as adequate allowance is made in MOTAD model for covariance between enterprise net returns by recognizing the mutually exclusive nature of the sample vectors of activity net returns together with their relative frequencies. Data availability results in expectations being based on the past 17 years' experience.

3. For an excellent review on QP model, See Hazell (6).
4. See Kennedy and Francisco (9), Schluter (12) and Thomas *et al.* (15).
5. Sample mean net returns are used here as expected values. But they need not be the same.

For the purpose of this study it is assumed that the yield risk is overwhelming in drought-prone areas as compared to product price risk and hence price variability is not considered in our models (constant product prices of 1974-75 are used) and the input costs are assumed to be fixed between years and hence constant input costs are used to compute net returns.

The Data

The data for this study were obtained both from farmers and secondary sources. Bijapur taluk in Bijapur district in Karnataka State was purposively[6] selected for the study. Field data on input and output for crops and dairy enterprises on farms were obtained from 113 (42 small, 41 medium and 30 large)[7] randomly selected farmers. Secondary data on area, production and productivity of food and non-food crops (local varieties) for 17 years (1955-1972) were obtained from District Statistical Officer, Bijapur. Input-output data for high-yielding varieties (HYVs) and local crops on farmer's fields were obtained from Annual Progress Reports (1972 and 1973) of Regional Research Station, Bijapur. The input-output coefficients for the recommended crop practices were derived making use of the publication, "Package of Practices for High Yields" (17). Similarly, input-output coefficients for recommended dairy activities were developed from "A Comprehensive Co-ordinated Plan for the Development of Drought Prone Areas in Karnataka" (18). Output prices for 1974-75 were obtained from the regulated market, Bijapur. Input prices during 1974-75 were obtained from farmers, local input dealers and Agricultural Extension Officers.

The Activities

Five local crop activities (cotton, jowar, wheat, safflower and Bengal gram) and three recommended crop activities (HYV[8] wheat, jowar and safflower) were included. Six dairy activities (five local and one cross-bred) were also included. Besides, bullock labour hiring, capital borrowing, dung and fodder purchase activities were also considered in the model.

The Constraints

Land[9] is included as one of the constraints in the model. Considering labour restrictive periods and supply restrictions,[10] 12 monthly (January

6. It is being considered as one of the severely drought-prone tract with a very high (>30 per cent) coefficient of variation of monthly (June to September) rainfall.

7. Farmers were categorised into small (upto 4 hectares), medium (4 to 8 hectares) and large (8 hectares and above). From each size category, ten per cent of the holdings were randomly selected for the study.

8. Wheat: Bijaga yellow; jowar: 5-4-6; and safflower: 7-13-3.

9. Land requirement for a unit of cow and buffalo was estimated at 0·00008 and 0·00012 hectare, respectively (5).

10. For computing labour supply (in other words, labour quota) for each farm during the restrictive periods, the total number of man equivalent workers (which mainly included cultivators and agricultural labourers) in the cluster of villages in and around the sample villages were worked out. The total cultivated area in these villages was also noted. The available man equivalent days were multiplied by the effective calendar days to get the total man-days available for each period for the whole area. This was divided by the total cultivated area to arrive at the quota for each hectare of land in each period. (It was found that man-days quota for each month per hectare in the study area was 6·63.) Similarly, bullock labour quota was fixed for each hectare of land for each month (worked out at 1·0) as per the study report of World Bank (4). Explicit consideration of labour supply restriction in each restrictive period while programming is thus the novelty of this study which is never reported in earlier studies.

through December) restrictive periods for human labour and eight for bullock labour (May through December) were identified. While programming, since the available human labour on the selected farms exceeded the quota, the whole quantity was used as the only available labour during that period and hence labour hiring was not allowed. Since they did not maintain any bullocks, bullock labour hiring was allowed only upto the quota level. Capital (credit) is considered as one of the overriding barriers for growth of drought-prone farms. Hence, we have included it as one of the binding constraints in our model. Restricted credit in our model refers to the capital position as indicated by the existing plan, while unrestricted credit refers to unlimited capital availability.

To support dairy and to maintain bullocks fodder is important. In the drought-prone areas, fodder is often considered as one of the severe constraints as its availability is linked with the production of the main crop. The crops selected should therefore meet the minimum requirements of fodder as well. Hence, minimum fodder requirement constraints were included.

Dung is one of the important sources of organic manure which is essential for maintaining soil fertility. In the study area, dung is often made into cakes and used as fuel. To discourage this practice and to ensure dung availability for crop production, dung was considered as a constraint and included in the models.

Coefficients

Gross returns were computed for the local crops for the 17 years from the data on historic yield and constant product prices of 1974-75. Variable costs[11] on these crops for 1974-75 were deducted from the gross returns to get net returns. Similarly, net returns for dairy were calculated by deducting operational costs[12] from gross returns from dairy. To estimate net return series for recommended varieties of crops, the following procedure was adopted: the average yields of recommended varieties of crops on farmer's fields were obtained. These were divided by the yields of the local varieties to get a factor of proportionality. This factor was used to blow up yield figures of locals to generate yield series for high-yielding ones. Gross returns were then computed making use of the product prices of the HYVs. From the gross return series, net return series were generated by deducting the constant estimated variable cost of production of HYVs. This method, we admit, may amount to assuming similar year to year variability in yields for high-yielding and local varieties. But we should note that variability in net returns for high-yielding and local varieties is not similar as we are using different product prices and costs of production. Since our final choice rests on variability in

11. It included expenses on seed and manure, labour, fertilizer and plant protection and use depreciation of implements.

12. It is the sum total of the expenses of feeds, fodder, labour, medicine, depreciation on the price of the animal for the year, insurance premium and apportioned depreciation of dairy equipment.

Input (resource) coefficients were computed as average quantities of various restrictive resources required per unit of a process or an activity.

net returns, the assumption of similar variance for yields for high-yielding and local varieties does not seem to be demanding. Since returns from dairy are already discounted with insurance premium,[13] dairy activities were included with 'zero' net returns deviations in the risk plans. These net return figures (both for local and HYV) for 17 years were corrected for trend[14] and change in the method of estimation over the years whenever it was required as per indications of the significance of the dummy variables. Bansil (2) mentioned that there were changes in the methods of estimation[15] of yield of some crops during the time span considered in this study. Jowar fell in the period with the same estimation method. For those crops where change in the method of estimation was reported, dummy variable approach was used along with second degree curve. However, dummies were found to be insignificant in the case of wheat, Bengal gram and cotton, thereby indicating that there was no actual difference in the method of estimation between the two time periods. In the case of groundnut and safflower, dummies were retained as they were significant. The residuals from these trend equations provided net return deviations. The normal distribution was fitted to the historical net returns of crops. The goodness of fit was tested with the help of X^2 and Kolmogorov-Smirnov tests (13). They indicated that the net returns of these crops followed a normal distribution.[16]

Since few people are used to thinking in terms of income mean deviations we computed the income standard deviations using the relationship:

Standard Deviation $= d\ (\pi\ s/2\ (s-1))^{\frac{1}{2}}$ where, s = number of observations in the sample, $\pi = 22/7$, and 'd' is the estimated mean absolute deviation (6).

The standard deviations for the existing plans were worked out using the total deviations for the crop per acre per year based on the mean deviation of the individual years. Such deviations were multiplied based on the area put to the crop and finally added based on the crops grown on the farm.

Coefficient of variation of net return for each plan was worked out using the net returns and the corresponding standard deviations.

RESULTS AND DISCUSSION

As stated elsewhere, our main objective was to evolve an enterprise system for stability and growth on small and large farms in the Bijapur arid agriculture. We have attempted this by examining the impact of optimiza-

13. Insurance premium was fixed making use of the reported mortality rates of dairy animals.

14. The graphical examination of the historical yield data suggested a second degree curve for the trend analysis. The fitted curve was of the type $Y = a + a_1 D + bX + cX^2$, where Y=net returns and X = time period. D is dummy coefficient, D=0 in time period 1 (pre-change period), D=1 in period 2 (post-change period).

15. The reported change in the method of estimation for various crops occurred during the years: wheat and Bengal gram: 1957-58; groundnut: 1958-59; safflower: 1961-62, and cotton: 1963-64.

16. Probability statements with respect to the likelihood of occurrence of different return levels for a given farm plan are only possible if the net return distribution is known. If total net returns can be expected to be approximately normally distributed, then such probability statements can easily be derived using tables for the normal deviate statistic. However, it is reported that MOTAD model has an advantage for skewed outcome distributions.

tion, better farm technology,[17] credit and bullock labour and dairy enterprises on land utilization, farm returns and farm labour employment (both human and bullock) by comparing the existing and the series of risk minimized plans obtained through PLP.

A. *Effects of Resource Optimization and Better Crop Technology on Land Utilization, Farm Returns and Labour Employment*

While it is widely accepted that optimum use of farm resources will increase farm returns, it becomes a difficult task on drought-prone farms, because of uncertainties in production and prices, and market imperfections. Our analysis and discussion in this section is mainly centred round these issues.

In Tables I and II,[18] restricted credit refers to farmer's own capital (as is being used in the existing plan).[19] Human labour in different restrictive periods is put at that which is available on the farm (hiring was not allowed). Since they did not own bullocks, bullock labour hiring was allowed upto the quota level. The farm resources were allocated efficiently. Besides local cotton, jowar, wheat, safflower and Bengal gram, HYVs of wheat, safflower and jowar were also included.

Effects on land utilization: In the existing plan, all the available land both on the small and large farm, was put to use. This is not difficult to explain as farmers in drought-prone areas try to cultivate all of their land to get some income. The limited resources will thus be largely spread resulting in lower returns. Further, a wrong crop-mix may not only reduce returns but add to its instability. This perhaps explains lower returns and higher risk in the existing plans and higher returns and lower risk in the risk minimized optimum plans.

In most of the optimum plans on small farms, the process of optimization has helped in bringing the entire farm area into use. However on the large farm, around 60 per cent of the land remained slack in most of the optimum plans. Thus our finding that large farmers would be better off by keeping a significant part of their land idle will look surprising if not impossible particularly because in this instance, besides land, resources like credit (capital) and human labour remain under-utilized. Further, the optimal plans recommended may sound curious also because in the existing plan all the land is utilized. This we attribute to resources (mainly seasonal bullock labour) becoming more binding and relatively lower level of expected net returns in the net return constraint. Thus, fixing a rigid bullock labour constraint particularly for large farmers may not be very realistic since they usually

17. Better farm technology means either high-yielding varieties of crops and breeds of animals or better local varieties/breeds. It is to be noted here that the yield (average over the years) of crop varieties included in the PLP plans are higher than the yield of the corresponding varieties in the existing plan of the farmers.

18. For want of space, not all points in the frontier are shown in these tables. Only the first, the last and a few intermediate points are shown as different plans (1 to 7) in these tables. The first plan can be considered as the safest plan, the last one riskiest and the intermediate ones as mediocres

19. This is said to consist of past savings and some borrowings.

TABLE I—EXISTING AND OPTIMAL PLANS WITH MINIMIZED RISK (EFFICIENT PLANS) DERIVED THROUGH PARAMETRIC LINEAR PROGRAMMING FOR A SMALL FARM (1·62 HECTARE) ON HEAVY SOILS WITH RESTRICTED CREDIT AND BULLOCK LABOUR WITHOUT DAIRY, BIJAPUR, KARNATAKA, 1955-1972

Sr. No.	Cropping plan	Existing plan	1	2	3	4	5	6	7
1.	Land used (hectare)	1·62	1·20	1·61	1·62	1·62	1·62	1·62	1·17
2.	Net returns (Rs.) ..	421	289	373	434	478	531	576	725
3.	Minimized standard deviations (Rs.) ..	194	29	42	51	61	77	96	184
4.	Coefficient of variation of net returns (per cent) ..	46	10·36	11·27	11·96	12·92	14·66	16·76	25·45
5.	Cotton (local) (hectare)	—	0·56 (35)	1·09 (67)	1·00 (62)	0·94 (58)	0·89 (55)	0·82 (51)	—
6.	Jowar (local) (hectare)	1·01 (62)	0·19 (12)	0·27 (17)	0·35 (21)	0.36 (22)	0·53 (33)	0·57 (55)	1·17 (72)
7.	Wheat (local) (hectare)	0·61 (38)	0·07 (4)	0·04 (3)	0·11 (7)	0·19 (12)	0·11 (7)	0·19 (7)	—
8.	Safflower (local) (hectare)		0·38 (23)	0·20 (12)	0·14 (9)	—	—	—	—
9.	Bengal gram (hectare)	—	—	0·01 (1)	0·02 (1)	0·06 (3)	0·06 (3)	0·04 (2)	—
10.	Wheat (HYV) (hectare)	—	—	—	—	—	—	—	—
11.	Safflower (HYV) (hectare)	—	—	—	—	0·07 (5)	0·03 (2)	—	—
12.	Jowar (HYV) (hectare)	—	—	—	—	—	—	—	—
13.	Buffalo (local) (number)	—	—	—	—	—	—	—	—
14.	Human labour (days)	119	17	18	18	21	19	19	16
15.	Bullock labour (days)	15	7	8	8	10	10	9	9
16.	Total capital (Rs.)	929	135	161	172	287	219	186	160

Note:—Figures in parentheses denote percentages.

TABLE II—EXISTING AND OPTIMAL PLANS WITH MINIMIZED RISK (EFFICIENT PLANS) DERIVED THROUGH PARAMETRIC LINEAR PROGRAMMING FOR A LARGE FARM (15·40 HECTARES) ON HEAVY SOILS WITH RESTRICTED CREDIT AND BULLOCK LABOUR, WITHOUT DAIRY, BIJAPUR, KARNATAKA, 1955-72

Sr. No.	Cropping plan	Existing plan	1	2	3	4	5	6	7
1.	Land used (hectare)	15·40	5·70	6·36	6·70	6·74	6·69	7·39	5·56
2.	Net returns (Rs.) ..	2,656	1,375	1,669	2,142	2,180	2,534	3,009	3,448
3.	Minimized standard deviations (Rs.) ..	1,325	142	185	303	313	427	609	877
4.	Coefficient of variation of net returns (per cent) ..	49	10·36	11·09	14·15	14·40	16·88	20·26	25·45
5.	Cotton (local) (hectare)	6·48 (42)	2·67 (17)	3·27 (21)	3·43 (22)	3·45 (22)	3·00 (19)	3·21 (21)	—
6.	Jowar (local) (hectare)	5·27 (34)	0·92 (6)	1·12 (7)	2·19 (14)	2·28 (15)	2·94 (19)	4·18 (27)	5·56 (36)
7.	Wheat (local) (hectare)	2·84 (19)	0·33 (2)	0·54 (4)	0·05 (32)	—	—	—	—
8.	Safflower (local) (hectare)	—	1·78 (12)	1·29 (8)	0·50 (3)	0·44 (3)	—	—	—
9.	Bengal gram (hectare)	0·81 (5)	—	0·14 (1)	0·53 (3)	0·57 (4)	0·75 (5)	—	—
10.	Safflower (HYV) (hectare)	—	—	—	—	—	—	—	—
11.	Wheat (HYV) (hectare)	—	—	—	—	—	—	—	—
12.	Jowar (HYV) (hectare)	—	—	—	—	—	—	—	—
13.	Human labour (days)	235	81	86	91	91	93	81	74
14.	Bullock labour (days)	85	34	38	44	44	48	42	43
15.	Total capital (Rs.) ..	1,799	647	724	807	737	860	785	705

Note:—Figures in parentheses denote percentages.

overcome seasonal shortage of bullock labour either by hiring bullock labour or tractor. A higher optimum with fuller utilization of resources could have been obtained had we relaxed the bullock labour constraint. This is a shortcoming of the present study.

Another important point that needs some explanation is the general land use pattern. Land utilization was higher in the intermediate plans than either in the few first or the last plans. Perhaps this has resulted in larger use of labour and capital in these plans. This, we believe, is due to the *modus operandi* of our model itself. In the few first plans, smaller incomes are expected with greater concern for risk. Hence less risky crops like cotton occupy more areas. But as we proceed in the expected net return mean absolute deviation frontier, our concern for risk decreases and for income increases. In the intermediate level, we are concerned with both. To satisfy the higher income level, more areas will be under cultivation with considerable emphasis on high income crops. Similarly to contain risk, less risky crops also occupy significant areas in these plans. In the few last plans, high incomes are expected with least concern for risk. Hence high return and high risk crops, like jowar, are selected and low income and low risk crops like cotton are eliminated. Since these crops are resource intensive and resources being binding, some land will have to remain slack in these plans.

Farmers in their present plans grew jowar and wheat. Besides these crops, cotton was another important crop only on the large farm.

In the optimum plans on the small farm, cotton is a new crop activity suggested whose area gradually increased from the first plan, reached some higher level in the intermediate plans and finally was eliminated in the final plan. As against this, the area under jowar gradually increased right from the beginning and finally occupied the entire area in the last plan.

In the optimum plans on the large farm, cotton was suggested to cover the smaller area than in the existing plan. In the final plan, no area was suggested to be put under cotton.

We can notice that the area allocation between the plans under cotton for the small and large farms is not consistent. On the small farm, the area allocated under cotton in different plans varied between 35 and 67 per cent while on the large farm it was 17 to 22 per cent. This inconsistency, we believe, is very realistic as small farmers may prefer to have more acreage under safe crops as compared to large farmers.

On the large farm the area under jowar gradually increased and on the small farm, it occupied all the suggested area in the final plan.

Both on the large and small farms, areas suggested under crops like wheat, Bengal gram and safflower have not much of consequence. It should be mentioned here that the crops included in the PLP (other than HYV) may as well as be treated as new activities as their net returns are the average over the years. But we have treated them as the same since we are compelled to use the same input coefficients for want of data. However while interpreting the results, we refer to them as better local varieties as their net returns are higher than their counterparts on the selected farms.

Effects on farm returns: We know that the optimum use of farm resources increases farm returns by allocating the resources commensurate with their marginal value productivities. A better crop technology shifts the production function as the same resources can produce more output now than before and thus increase farm returns. By seeing the returns and the corresponding risk (standard deviations) associated with them both in the existing and optimum plans, we can infer that by optimizing and including better crops, farmers can get more returns than at the same or even at a lower level of risk that they are presently taking.[20] This is in conformity with our hypothesis that farmers in drought-prone areas are not efficient in their resource use and do not take advantage of the better crop varieties. We also found that one per cent increase in net returns increased risk by 1.97 per cent on the small farm and an almost similar percentage (2 per cent) on the large farm.

Effects on labour employment: We can see that there was definitely low use of labour (both human and bullock) in the optimum plans as compared to the existing plan. This was mainly due to bullock labour becoming too restrictive during the month of May (whose MVP increased from 8 to 895 in different plans). Within the set of optimum plans, labour employment was higher in the intermediate plans than in the few first and last plans. Perhaps, this facilitated the optimizing process more in the intermediate plans than in the few first and last plans, giving rise to greater land use. The larger availability of unused human labour on these farms may be conveniently used for some off-farm work or some labour using activities which can convert this idle resource into returns.

Capital though included as a constraint had never emerged as a constraint as can be seen from the capital used in the existing and optimal plans. Further, the low capital use in the initial plans is due to low capital requirement of crops suggested in the plan. This may also be due to under-utilization of land here. The higher use of capital use in the intermediate and final plan is due to increased use of land and high capital investment crops, respectively.

B. *Effects of Unrestricted Capital and Bullock Labour Use on Land Utilization, Farm Returns and Labour Employment*

Relaxing the resources will help to attain a higher point on the given production function and it thus helps to attain higher yields and incomes. With this idea, we have relaxed capital and bullock labour in this section and tried to examine their impact on land utilization, net returns and labour employment.

Though, in the first section, we have seen that capital was never used to the extent of availability, we still relaxed it in this section as we have relaxed another constraint which needs capital for hiring.

20. We are not sure if farmers prefer lower income levels with lower uncertainty to the present (existing) levels of higher income with higher risk. Obviously, farmers' own utility function is an important issue in decision-making, the role and nature of which has not been studied in the investigation. If it is assumed that farmers would not in any case like to lower existing incomes, our plans in the plan continuum below this level may not be so relevant to them.

Comparison of the results of the cropping plans with unrestricted capital and bullock labour use (Tables III and IV) with those of restricted capital and bullock labour use indicated the effects of capital and bullock labour. We have attempted this by introducing credit borrowing and bullock labour hiring activities.

Effects on land utilization: As we have anticipated, in general, the extent of land utilization has considerably improved when we have relaxed these two constraints. We did not see much changes in the cropping pattern except for the fact that the same crops occupied larger areas in these plans.

Effects on farm returns: As a result of relaxation of use of capital and bullock labour, we could see larger net returns forthcoming. But, the risk associated with net returns in each of these plans is definitely higher as can be seen from the coefficients of variation. However, the rate of increase of risk, associated with a given rate of increase in net returns within the set of plans, was lower here as compared to the restricted capital and labour use situation. It was 1.70 and 1.55 per cent on the small and large farms, respectively. This might be due to greater productivity of these inputs on a wider area, making net return move faster than risk.

Effects on labour employment: Labour employment (both human and bullock) significantly improved when capital use and bullock labour constraints were relaxed. But still we could see lot of unused human labour which can be gainfully employed. Increased availability of bullock labour is the main reason for increased use of land in the optimum plans.

As in the previous case, capital though relaxed was never used beyond what was available in the existing plan except for a few terminal plans on the large farm where such relaxation was marginally beneficial. Bullock labour turned out to be the most crucial factor for increasing farm returns.

Our findings in this section thus prove the hypothesis that increased use of crucial inputs like credit and bullock labour will not only increase net returns but add to some instability. However, if one is able to take risk, then he can go for these inputs as the rate of growth of risk in the plan continuum is smaller here than under restricted use of them.

C. *Effects of Dairy on Land Utilization, Farm Returns and Labour Employment*

In drought-prone areas livestock enterprises are often suggested as they are considered to have a comparative advantage. Hence, in our study, we have included dairy enterprises besides crop enterprises to see their impact on land utilization, farm returns and labour employment. We could study the impact by comparing the final plans as details were not worked out for all the plans for want of funds. Dairy was included (with zero return deviations) in the risk plans. Farm resources were allocated among crop and dairy enterprises efficiently. Comparison of farm plans with dairy and without dairy indicated the effects of dairy.

A comparison of the plans (Table V) with dairy and without dairy (Tables III and IV) indicated the superiority of the plans with dairy both

TABLE III—EXISTING AND OPTIMAL PLANS WITH MINIMIZED RISK (EFFICIENT PLANS) DERIVED THROUGH PARAMETRIC LINEAR PROGRAMMING FOR A SMALL FARM ON HEAVY SOILS WITH UNRESTRICTED CREDIT AND BULLOCK LABOUR, WITHOUT DAIRY, BIJAPUR, KARNATAKA, 1955-1972

Sr. No.	Cropping plan	Existing plan	1	2	3	4	5	6	7
1.	Land used (hectare)	1·62	1·62	1·62	1·62	1·62	1·62	1·62	1·62
2.	Net returns (Rs.)	421	274	361	387	477	766	854	857
3.	Minimized standard deviations (Rs.)	194	40	59	67	101	212	255	306
4.	Coefficient of variation of net returns (per cent)	46	14·76	16·52	17·42	21·15	27·71	29·94	35·69
5.	Cotton (local) (hectare)	—	0·76 (47)	1·06 (65)	0·97 (60)	0·75 (46)	—	—	—
6.	Jowar (local) (hectare)	1·01 (62)	0·26 (16)	0·38 (24)	0·46 (28)	0·65 (40)	1·38 (85)	1·62 (100)	1·43 (88)
7.	Wheat (local) (hectare)	0·61 (38)	0·09 (6)	0·16 (10)	0·12 (8)	0·11 (7)	—	—	—
8.	Safflower (local) (hectare)	—	0·51 (31)	—	—	—	—	—	—
9.	Bengal gram (hectare)	—	—	—	0·05 (3)	0·11 (7)	0·24 (15)	—	—
10.	Wheat (HYV) (hectare)	—	—	—	—	—	—	—	—
11.	Safflower (HYV) (hectare)	—	—	0·02 (1)	0·02 (1)	—	—	—	—
12.	Jowar (HYV) (hectare)	—	—	—	—	—	—	—	0·19 (12)
13.	Buffalo (local) (number)	1	—	—	—	—	—	—	—
14.	Human labour (days)	119	23	17	19	21	28	22	27
15.	Bullock labour (days)	15	10	8	9	11	16	13	15
16.	Total capital (Rs.)	929	184	195	203	199	258	208	427

Note:—Figures in parentheses denote percentages.

TABLE IV—EXISTING AND OPTIMAL PLANS WITH MINIMIZED RISK (EFFICIENT PLANS) DERIVED THROUGH PARAMETRIC LINEAR PROGRAMMING FOR A LARGE FARM ON HEAVY SOILS WITH UNRESTRICTED CREDIT AND BULLOCK LABOUR WITHOUT DAIRY, BIJAPUR, KARNATAKA, 1955-1972

Sr. No.	Cropping plan	Existing plan	1	2	3	4	5	6	7
1.	Land used (hectare)	15·4	9·74	15·4	15·4	15·39	15·4	15·4	15·4
2.	Net returns (Rs.) ..	2,656	1,627	2,605	3,111	4,473	6,894	7,561	8,047
3.	Minimized standard deviations (Rs.)	1,325	243	295	490	960	1,886	2,293	2,431
4.	Coefficient of variation of net returns (per cent)	49	14·97	15·18	15·75	21·46	27·36	29·00	30·21
5.	Cotton (local) (hectare)	6·48 (42)	4·55 (30)	6·89 (45)	9·44 (62)	7·12 (46)	—	—	—
6.	Jowar (local) (hectare)	5·27 (34)	1·57 (10)	2·72 (18)	3·32 (21)	6·15 (40)	11·60 (75)	14·09 (91)	15·40 (100)
7.	Wheat (local) (hectare)	2·84 (19)	0·56 (4)	0·79 (5)	0·99 (6)	1·09 (7)	1·05 (7)	—	—
8.	Safflower (local) (hectare)	—	3·06 (20)	5·00 (32)	1·49 (10)	—	—	—	—
9.	Bengal gram (hectare)	0·81 (5)	—	—	0·16 (1)	1·03 (7)	2·75 (18)	1·31 (9)	—
10.	Wheat (HYV) (hectare)	—	—	—	—	—	—	—	—
11.	Safflower (HYV) (hectare)	—	—	—	—	—	—	—	—
12.	Jowar (HYV) (hectare)	—	—	—	—	—	—	—	—
13.	Human labour (days)	235	139	222	177	200	287	241	205
14.	Bullock labour (days)	85	59	94	80	101	158	137	119
15.	Total capital (Rs.) ..	1,799	1,045	1,664	1,524	1,790	2,466	2,126	1,872

Note:—Figures in parentheses denote percentage.

TABLE V—EXISTING AND OPTIMAL PLANS WITH MINIMIZED RISK (EFFICIENT PLANS) FOR A SMALL AND LARGE FARM ON HEAVY SOILS WITH UNRESTRICTED CREDIT, BULLOCK LABOUR AND DAIRY, BIJAPUR, KARNATAKA, 1955-1972

Sr. No.	Enterprise plans	Size-group of farm	Existing plan	1	2	3	4	5	6	7
1.	Net returns (Rs.)	Small Large	421 2,656	398 952	1,573 10,851	3,361 12,130	4,054 14,473	4,490 15,231	4,515 16,598	4,559 17,222
2.	Minimized standard deviations (Rs.)	Small Large	194 1,325	21 52	89 623	213 738	297 1,434	465 1,744	485 2,441	592 2,966
3.	Coefficient of variation of net returns (per cent)	Small Large	46 49	5·42 5·51	5·67 5·74	6·34 6·08	7·33 9·91	10·37 11·45	10·75 14·71	12·98 17·40

in terms of net returns and stability. We could see that net returns are not only higher here but are relatively stable (lower coefficient of variation). Further, the rate of increase of risk is also lower. It was 1.25 and 1.28 per cent for the small and large farms respectively.

Effects on land utilization: On the small farm, in the final plan 0.37 hectare of local jowar, 1.25 hectare of HYV jowar and 5 local cows were suggested as compared to 1.43 hectare of local jowar and 0.19 hectare of HYV jowar. The increased area under HYV of jowar in the final plan with dairy is to satisfy the fodder constraints included in the model.

On the large farm, 9 hectares of local jowar and 3.57 hectares of HYV jowar were suggested besides 13 local cows as compared to only local jowar on all the farm area. Some land did remain slack here for not want of capital or bullock labour but for want of human labour in February and November months. This is quite understandable as dairy activities need lot of human labour in different months. As on the small farm, the larger appearance of HYV jowar here is mainly due to the dairy activities which needed fodder.

Effects on farm returns: On the small farm the net return was Rs. 4,559 and the corresponding level of risk was Rs. 592. On the large farm, it was Rs. 17,222 and the corresponding level of risk was Rs. 2,966. Thus, we could see larger net returns here with more stability.

Effects on labour employment: As a result of inclusion of dairy, both human and bullock labour employment improved. As high as 397 human labour days and 31 bullock labour days were used on the small farm while on the large farm, the corresponding figures were 1,193 and 150 days, respectively. This gives us a clue that if dairy enterprises are encouraged in these areas idle labour can be gainfully employed throughout the year.

If we look to capital use in these final plans, we must conclude that they are capital intensive. As high as Rs. 3,045 and Rs. 11,767 are used besides own capital on the small and large farms, respectively. Thus, capital really becomes a constraint when dairy activities are suggested in farm plans along with crop activities. If such activities are to be encouraged, massive capital assistance should go hand in hand. Perhaps, human labour may also become a demanding resource at least in some periods, if dairy is included beyond some level.

Our findings in this section confirm the truth of the hypothesis we stated earlier that mixed farming (with dairy) can not only increase net returns but can add stability to it.

POLICY IMPLICATIONS

(1) Farmers in the area should be advised to follow the enterprise plans with better varieties of crops (jowar and cotton) and breeds of cows.

(2) For optimum use of farm resources (especially land and family labour) in generating larger incomes by adopting the suggested plans, additional capital and bullock labour facility should be made available. As a method to augment bullock labour resource, tractor cultivation may be en-

couraged in these areas. Jodha (8) maintains that due to high cost of bullock maintenance as a result of serious under-utilization of bullock power and due to limited wet periods of 2 to 4 weeks for the whole season in drought-prone areas tractor cultivation is more feasible than bullock cultivation. Tractor on hiring service basis may therefore be introduced in such areas which can also provide transport facilities to these areas. This should be seen in the light of lesser road length per unit area and many villages not at all connected by roads in this region.

(3) If dairy as included in these plans is popularised, then better veterinary health cover, fodder facilities, special marketing arrangements for handling animal products are needed in this area. To support such dairy activities, pasture growing in sub-marginal lands should be considered. Dung manure from dairy should be exclusively used for crop production instead of making cakes (as fuel) as at present. Afforestation may be done not only to augment fuel supplies in the region but also to improve the micro-climate of the region.

(4) For movement of cotton and animal products (especially food and fodder during drought years) a vast network of motorable roads connecting all the villages in the district is badly needed. The importance of surfaced roads in such regions hardly needs emphasis. William Easter *et al.* (19) found that the absence of roads in a heavy rainfall area such as the eastern rice region in India had the effect of raising input prices paid by farmers and lowering output prices received by them due to higher transportation costs. In the same region, Spriggs (14) has estimated a benefit-cost ratio of expansion of surface roads in the neighbourhood of 8:1.

REFERENCES

1. James S. Ang, "Reliability of Using the Mean Absolute Deviation to Derive Efficient E, V Farm Plans: Comment", *American Journal of Agricultural Economics*, Vol. 55, No. 4, November 1973, pp. 675-677.

2. P. C. Bansil: Agricultural Statistics in India, Dhanpat Rai and Sons, Jullundur-Delhi, 1970.

3. Joyce T. Chen, "A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning under Uncertainty : Comment", *American Journal of Agricultural Economics*, Vol. 53, No. 4, November 1971, pp. 662-663.

4. Government of Karnataka: Economic Development of Bijapur District under Drought Prone Areas Programme with World Bank Assistance, Directorate of Project Formulation, Bangalore, Karnataka, 1973.

5. P. L. Guglani: The Impact of High Yielding Varieties of Wheat on Farm Resource Use, Income and Production in the Rural Areas of the Union Territory of Delhi, unpublished Ph.D Thesis, Faculty of Agriculture, Agra University, Agra, 1972.

6. P. B. R. Hazell, "A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning under Uncertainty", *American Journal of Agricultural Econcmics*, Vol. 53, No. 1, February 1971, pp. 53-62.

7. P. B. R. Hazell, "A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning under Uncertainty: Reply," *American Journal of Agricultural Economics*, Vol. 53, No. 4, November 1971, pp. 664-665.

8. N. S. Jodha, "A Case of the Process of Tractorisation," *Economic and Political Weekly*, Vol. IX, No. 52, December 28, 1974.

9. J. O. S. Kennedy and E. M. Francisco, "On the Formulation of Risk Constraints for Linear Programming", *Journal of Agricultural Economics*, Vol. XXV, No. 2, May 1974, pp. 129-146.

10. Mruthyunjaya: An Economic Analysis of Risk on Drought Prone Farms in Bijapur District, Karnataka, unpublished Ph. D. Thesis, Division of Agricultural Economics, Indian Agricultural Research Institute, New Delhi, 1976.

11. Mruthyunjaya and A. S. Sirohi, "An Economic Analysis of Crop Yield and Product Price Variability in Bijapur Arid Agriculture, Karnataka", *Annals of Arid Zone*, (forthcoming).

12. M. G. G. Schluter: The Interaction of Credit and Uncertainty in Determining Resource Allocation and Income on Small Farms, Surat District, India, Occassional Paper No. 68, Department of Agricultural Economics, Cornell University, Ithaca, New York, U.S.A., 1974.

13. S. Siegal: Non-parametric Statistics for the Behavioural Sciences, McGraw Hill, Kogakusha Company Ltd., Tokyo, 1956.

14. John Spriggs, "Benefit-Cost Analysis of Surfaced Roads in the Eastern Rice Region of India" *American Journal of Agricultural Economics*, Vol. 59, No. 2, May 1977, pp. 375-379.

15. Wayne Thomas *et al.*, "Separable Programming for Considering Risk in Farm Planning", *American Journal of Agricultural Economics*, Vol. 54, No. 2, May 1972, pp. 260-266.

16. K. J. Thomson and P. B. R. Hazell, "Reliability of Using the Mean Absolute Deviation to Derive Efficient E, V Farm Plans", *American Journal of Agricultural Economics*, Vol. 54, No. 3, August 1972, pp. 503-506.

17. University of Agricultural Sciences: Package of Practices for High Yields, Bangalore, Karnataka, 1974.

18. University of Agricultural Sciences: A Comprehensive Co-ordinated Plan for the Development of Drought Prone Areas in Karnataka, Bangalore, Karnataka, 1975.

19. K. William Easter *et al.*, "Regional Differences in Agricultural Productivity in Selected Areas of India", *American Journal of Agricultural Economics*, Vol. 59, No. 2, May 1977, pp. 257-265.