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IDENTIFICATION AND EVALUATION OF OPTIMAL CROPPING SYSTEMS FOR A TYPICAL WATERSHED IN UTTAR PRADESH HILLS*

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A watershed may be viewed as a biophysical system characterized by a number of interdependent and mutually interacting biophysical phenomena and processes. This means that an induced change in any one or more of these phenomena and processes would initiate a series of changes in the rest of the system. It is because of this characteristic that a watershed has now been accepted as the most appropriate unit for land use and crop planning particularly in the hill areas all over the world. If a watershed is used as a unit for formulating a resource use and development plan, most of the externalities inherent in such a plan are internalized making the task of formulating and evaluating the projects easier and simpler. In this paper, an attempt has been made to develop a few alternative optimal cropping systems for a typical sub-watershed in the hill region of Uttar Pradesh drawing upon the data and experience of the Rural Area Planning Research and Action Project (RAPRAP).

RESEARCH PROCEDURE

The study was conducted in a typical sub-watershed, namely, Adbora, in the Ramganga watershed. The total geographical area of the Adbora sub-watershed is 44.45 hectares which supports a population of 233 persons. There were 32 farm households in the sub-watershed and the average size of the cultivated land holdings was about 0.61 hectare.

An aggregative linear programming model was used to formulate a set of five alternative optimal crop plans for the land suitable for cultivation (LSC) in the sub-watershed and the partial budgeting technique was used to identify the most profitable use of the land suitable for permanent vegetation (LSPV). The objective function of the linear programming model was to maximize the returns over variable cost (ROVC) subject to the constraints imposed by availability of resources and other farm and farm household requirements. The activities included in the sub-watershed model consisted of all the traditional and newly introduced foodgrain and vegetable crops grown in the area. For LSPV, only two activities, namely, mixed fruit orchard and pasture, were considered.

* This paper is mainly based on the work done by the authors under a multi-disciplinary research-cum-extension project called the Rural Area Planning Research and Action Project (RAPRAP). RAPRAP was launched in a typical watershed in Almora district in August 1973 with the Ford Foundation's financial assistance and was concluded in May 1976. The authors are thankful to Dr. S.L.Shah, Professor and Head, Department of Agricultural Economics, who was also the Co-ordinator of RAPRAP, for providing the necessary facilities and a congenial environment for completing this work.

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A land capability survey conducted in the sub-watershed by RAPRAP soil science group furnished information about the land use classes, their extent and inherent suitability for various uses. Information on the existing crop pattern, yield rates, input use levels, and availability of labour, cash and credit, farm and farm household requirements, etc., was collected by an agro-economic survey of all the farm households in the sub-watershed. The price data were obtained from the local shop-keepers and Government seed-cum-fertilizer depots. Information on new crops/crop varieties, including input-output coefficients was collected from the field records of the crop demonstrations conducted in the area by RAPRAP scientists.

For formulating alternative crop plans the total geographical area of the sub-watershed was divided into two broad classes—LSC and LSPV. Land within each class was again sub-divided into a number of sub-classes according to certain physical characteristics of the soil. The estimates of availability of other resources were based on simple aggregation of resources available with the farmers living in the area.

RESULTS AND DISCUSSION

The results of the study are presented and discussed under two headings, namely, alternative crop plans for land suitable for cultivation (LSC) and land use plans for land suitable for permanent vegetation (LSPV).

Alternative Crop Plans for LSC and Their Evaluation

Five alternative crop plans were formulated for the sub-watershed, *viz.*,

Alternative 1 (A_1) : Optimum crop plan with existing technology;

Alternative 2 (A_2) : Optimum crop plan with improved technology and no credit;

Alternative 3 (A_3) : Optimum crop plan with improved technology and limited credit;

Alternative 4 (A_4) : Optimum crop plan with improved technology and as much credit as needed; and

Alternative 5 (A_5) : Optimum crop plan with improved technology, limited credit and *mandua* and *rabi* fallow at one-half of their pre-determined levels.

Table I contains alternative crop plans for the watershed. In the *kharif* the crop pattern under A_1, *mandua*+*urd* accounted for about 32 per cent and paddy+*jhungra* for about 21 per cent of the total cropped area. Among cash crops, chillies, summer potato (rainfed) and *rabi* potato (rainfed) were equally important, each accounting for about 5 per cent of the total cropped area. Only 0.70 per cent of the total cropped area was allocated to tomato.

When improved technology was introduced in A_2 with no credit, the optimal crop pattern changed drastically. Paddy (local) was completely eliminated mainly by *mandua* and partly by soyabeans and high-yielding paddy (IR-24). *Mandua* (pure) accounted for as high as 54 per cent of the total cropped area. Paddy IR-24 and soyabeans—a newly introduced crop—

TABLE I—ALTERNATIVE CROP PLANS FOR ADBORA SUB-WATERSHED

Crop activities	Alternative crop plans (as per cent of total cropped area)				
	A1	A2	A3	A4	A5
1. Paddy (local)+*jhungra*	21·72	0	0	0	0
2. Paddy (IR-24)	0	3·86	3·68	1·64	3·61
3. Paddy (Bala)	0	0	0	0	0
4. *Mandua+urd*	31·92	0	0	0	0
5. *Mandua+bhat*	2·62	0	0	0	0
6. *Mandua+gauhat*	2·62	0	0	0	0
7. *Mandua*	0	53·73	36·25	23·03	35·61
8. Capsicum	0	0	0	0·66	0
9. Chillies	5·24	1·76	1·67	1·64	1·64
10. Tomato	0·70	0·70	0·67	0·66	0·66
11. French beans	0	0·70	0·67	0·66	0·66
12. Soyabeans	0	8·16	22·61	34·86	22·21
13. Summer potato (rainfed)	{5·24	0	0	0	0
14. Summer potato (irrigated)		0	0	1·32	0
15. *Rabi* potato (rainfed)	{5·24	0	0	0·66	0
16. *Rabi* potato (irrigated)		0	0	1·32	0
17. Wheat (local) + barley/*lahi*/lentils	24·70	30·39	29·43	27·63	34·95
18. HYV wheat	0	0	4·35	4·60	0
19. Peas	0	0·70	0·67	0·66	0·66
20. Oats (fodder)	0	0	0	0·66	0
Total cropped area	100·00	100·00	100·00	100·00	100·00
Rabi fallow as per cent of total cultivated area	22·45	22·45	22·45	22·45	11·23

A1=Optimum crop plan with existing technology.
A2=Optimum crop plan with improved technology and no credit.
A3=Optimum crop plan with improved technology and limited credit.
A4=Optimum crop plan with improved technology and unlimited credit.
A5=Optimum crop plan with improved technology, limited credit and *mandua* and *rabi* fallow at one half of their pre-determined levels.

TABLE II—ECONOMIC CONSEQUENCES OF ALTERNATIVE CROP PLANS FOR THE SUB-WATERSHED

Measure of performance	A1	A2	A3	A4	A5
1. Returns over variable cost(ROVC) (Rs.)	53,909	75,040	87,327	1,01,907	87,957
2. Increase in ROVC over that of A1 (per cent)	—	39·20	62·00	89·02	63·16
3. Increase in ROVC over that of A2 (per cent)	—	—	16·37	35·80	17·21
4. Cash borrowed (Rs.)		0	2,650	10,020	2,650
5. Marginal value products of scarce factors (Rs.)					
(*i*) *Kharif* irrigated land	28[a]	42·73	42·73	98·20	42·73
(*ii*) *Kharif* rainfed land	40[b]	34·18	34·18	78·56	34·18
(*iii*) *Rabi* irrigated land	28[c]	0	0	44·96	0
(*iv*) *Rabi* rainfed land	0[d]	0	6·82	38·56	0
(*v*) *Kharif* cash(own)	0	3·82	3·82	0·12	3·82
(*vi*) *Rabi* cash(own)	0	3·33	3·33	0·12	3·33
(*vii*) *Kharif* credit	0	0	3·70	0	3·70
(*viii*) *Rabi* credit	0	0	3·21	0	3·21

a. Relates to paddy land.
b. Relates to other *kharif* land.
c. Relates to wheat land.
d. Relates to other *rabi* land.

accounted for about 4 per cent and 8 per cent of the total cropped area respectively. Among cash crops, potato was completely dropped from the plan and the area under chillies declined substantially. No land was devoted to high-yielding variety (HYV) wheat, rather a slight increase in the area under local wheat was noticed.

The optimal crop patterns were the same under A_3 and A_5 except that the area allocated to local wheat in A_5 was about 21 per cent higher than that in A_3 and that no area was allocated to HYV wheat in A_5 whereas 4.35 per cent of the total cropped area was allocated to this crop in A_3. When credit restriction was removed in A_4, the optimal crop pattern changed markedly. For example, there was a drastic reduction in the area under *mandua* from 54 per cent in A_2 and 36 per cent in A_3 to 23 per cent in A_4 and a drastic increase in the area under soyabeans from 8 per cent in A_2 and about 22.5 per cent each in A_3 and A_5 to 35 per cent in A_4. Several new activities, namely, summer and *rabi* potato (rainfed and irrigated), capsicum and oats which were not included in any other alternative plan appeared in A_4.

Table II presents data on a few selected measures of performance for all the alternative crop plans. Alternative A_4 has the largest ROVC of all the alternative crop plans prepared for the watershed. It was about 89 per cent higher than that of A_1. With limited credit and improved technology under A_3 and A_5, the ROVC was about 62 per cent higher than that of A_1. This indicates the role which institutional credit can play in increasing faım incomes in the area. The maximum amount of credit that would be needed to maximize ROVC worked out at Rs. 511 per hectare.

The fact that the marginal value products (MVPs) of credit range from Rs. 3.21 to Rs. 3.70 if new technology is used, indicates that the farmers can profitably use the new technologies introduced in the area. The zero MVP of credit in A_1 shows that it is not profitable to use credit under the traditional system of farming in the area. The MVPs of irrigated land under various alternatives give an idea of how much a farmer can except as returns to investment in developing irrigation facilities.

Self-sufficiecy in foodgrains is considered as one of the major goals of farmers in a traditional agriculture. An attempt was made to evaluate the alternative crop plans in terms of their potential to attain self-sufficiency in cereals. The data on total and per capita production of cereals under different crop plans are presented in Table III.

The total and per capita production of cereals was the highest in A_3 at the hundred per cent level of adoption of the optimal crop plans and the lowest in A_4 when the level of adoption is 50 per cent. At the hundred per cent level of adoption, all the optimal crop plans attain self-sufficiency. Self-sufficiency can be achieved under all the alternatives except A_4 even at the 75 per cent level of adoption. At the 50 per cent level of adoption, self-sufficiency can be attained only with A_1. The fact that self-sufficiency in cereals can be achieved with A_1 at all the three levels of adoption indicates that the existing crop pattern in the area is highly subsistence-oriented. A_4 which ranked

TABLE III—TOTAL AND PER CAPITA PRODUCTION OF CEREALS UNDER DIFFERENT ALTERNATIVE CROP PLANS

Optimum crop plan and extent of adoption	Total production (quintals)	Per capita production (kg./annum)	Total production as per cent of total consumption requirement
A_1			
100 per cent	384.84	193	118
75 per cent	356.91	173	109
50 per cent	328.98	165	101
A_2			
100 per cent	411.08	207	126
75 per cent	366.61	184	112
50 per cent	322.15	162	98
A_3			
100 per cent	440.58	221	135
75 per cent	361.41	182	110
50 per cent	319.07	160	98
A_4			
100 per cent	370.49	186	113
75 per cent	315.58	159	96
50 per cent	260.55	131	80
A_5			
100 per cent	411.17	207	126
75 per cent	359.00	180	110
50 per cent	306.53	154	94

TABLE IV—PLANS FOR USE OF 'OTHER LAND' AND THEIR CONSEQUENCES IN THE SUB-WATERSHED

Particulars	
1. Area of 'other land' (hectares)	
(a) Land suitable for orchards, pastures and forest vegetation	21·00
(b) Land suitable for pastures and forests	1·20
2. Land allocated to orchards	
Out of 1 (a)	5·25
Out of 1 (b)	0
Total	5·25
3. Land allocated to pastures	
Out of 1 (a)	15·75
Out of 1 (b)	1·20
Total	16·95
4. Returns over variable cost (ROVC) (Rs.)	
Orchards	14,434
Pastures*	33,916
Milch cows:	
Local	616 (7)
Improved	8,150 (10)
Buffaloes (local)	25,150 (50)

* ROVC from pastures is in terms of ROVC from milch animals mainly supported by the pastures.
Note:—Figures in parentheses represent the number of milch cows/buffaloes.

first in terms of ROVC is at the bottom of the list in terms of cereal production. This means income can be increased only by substituting cash crops for foodgrains.

Land Use Plans for LSPV

Plans for use of land suitable for orchards, pastures and forest vegetation were prepared by the partial budgeting technique. Since orchards and pastures were the only two activities that compete for the use of this class of land, linear programming would not be as efficient a tool for determining their optimum combination as partial budgeting.

Since most of the land falling in this class is owned jointly by the village community concerned, a separate land use plan was prepared to facilitate implementation of the plan. As shown in Table IV, the allocation of land between orchards and pastures is done strictly according to land capability. About 75 per cent of the land suitable for orchards, pastures and forest vegetation was allocated to pastures to meet the fodder requirement of the watershed and the remaining 25 per cent to orchards.

The returns over variable cost (ROVC) from orchards represent present value of future stream of returns and are based on the assumption that all the recommended practices will be followed for the management of orchards. The ROVC from pastures represent ROVC from the milch cows and buffaloes that are mainly supported by pastures. The total ROVC from community orchards and pastures amounted to Rs. 48,350 or Rs. 2,178 per hectare. This represents a substantial amount which can be realised by proper planning and management of this class of land. The actual benefits being realised by the people from such class of lands are only a very small fraction of the potential gains. What is needed to realise the potential gains is some kind of institution which could take care of planning and management of community land.

SUMMARY AND CONCLUSIONS

Plans prepared for the land fit for cultivation and owned privately showed that the returns over variable cost (ROVC) could be increased by as much as 89 per cent if improved technology were adopted and credit were available in needed quantities as compared to the case when an optimum crop plan is formulated using exsiting technology. Besides protecting the soil from erosion losses, orchards and pastures could yield ROVC of Rs. 48,350.

The cropping pattern followed traditionally in the hill region needs adjustment in view of the increased needs of the people for higher production and income as well as for maintaining ecologically sound environment. There is urgent need for an appropriate land use policy to discourage unwise and wasteful use of land and to promote ecologically sound farming systems.

Farm income and employment can be substantially increased by adopting improved farming system along with appropriate package of practices and inputs.

In order to enable the communities to derive full benefits from such lands, appropriate institution(s) need to be created for proper planning and management of these lands.

IMPACT OF RISK AND UNCERTAINTY ON FARM PRODUCTION AND INCOME IN THE HILLS OF THE NILGIRIS, TAMIL NADU

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Risk is now widely recognized as a critical factor in nearly all farming activities, and has become a major concern especially in relation with the adoption of new technology by farmers. Spurred by the recent violent fluctuations in prices of farm products, there has been an upsurge of interest in risk and uncertainty in farming. Economists realise that recognition of differing risk preferences of farmers may explain and perhaps even justify what appears to be economically irrational behaviour—holding reserves, diversification of production, attempting to minimize the probability of loss and such decision behaviours.

CONCEPTS

Uncertainty is a state of mind in which an individual perceives alternative outcomes to a particular action. Risk, on the other hand, has to do with the degree of uncertainty in a given situation. Defining risk is more than a semantic problem. One conclusion that emerged from the controversy over definitions, in a recent seminar,[1] was that precisely because there is no consensus about the meaning of risk and risk aversion researchers should specify which definition they are using. The measures of risk most commonly used by agricultural economists is the statistical measures of dispersion: Standard Deviation and Variance. Accepting this measure, risk is defined for this study as the variance in aggregate net farm income. There are several factors causing this risk in farm business.

Family health, and managerial ability to adopt new enterprises/technology are sources of risks internal to the business. Many other agricultural risks are external to the business: price risk, yield risk, technological change, changes in legal and institutional framework and changing monetary and fiscal conditions. These business risks interact with financial risks associated with operating, and financial leverages. Operating leverage

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1. James A. Roumasset, " 'Risk and Uncertainty' in Agricultural Development", A/D/C/Seminar Report No. 15, October 1977.