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FARMING SYSTEMS FOR EROSION CONTROL AND SUSTAINED PRODUCTION IN DRYLANDS OF THE OUTER HIMALAYAN REGION

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ABSTRACT

Optimal farm plans with existing as well existing plus improved technologies were developed for small and medium farm groups to maximize farm income and minimize soil loss using linear programming technique. The application of this technique to soil and water conservation problems has not been done before. A perusal of the optimal plans developed under various programming situations revealed that for small farms, minimization of soil loss with only exiting technology may not be acceptable as the farm income from such a plan was only Rs 2.999 though the soil loss was only 3.7 t ha^{-1} yr^{-1}. This income was much less than that from the existing (subsistence) plan (Rs 9,762). Farmers give more priority to having high farm income than to having low soil loss. In case of optimal plans for small farms developed with existing plus improved technologies. any of the two would be acceptable since both are giving better incomes than the present one (Rs 9.762). Hence for small farms improved technology would help a lot in improving the farm income without incurring high soil loss. In case of the medium farm category. minimization of soil loss with only existing technology would give almost the same income as from the present plan (Rs 16.876) but with a much lower level of soil loss (4.5 t ha^{-1} yr^{-1}). With improved technology, farm income would be more than double (Rs 35, 505) the existing level of income, and, that too at the same rate of soil loos (23 t ha^{-1} yr^{-1}). Minimization of soil loss with improved level of technology would also give a better inceome than the existing one but with a very low soil loss rate (3.9 t ha^{-1} yr^{-1}). Hence for medium farm category, though improved technology can boost the farm income with much lower or almost same rate of soil loss, even existing technology if optimally utilized can reduce soil loss without compromising the farm income. Thus the study concludes that efficient resource management with improved package of crop production technologies holds the key for prosperity.

I. INTRODUCTION

What really matters to the farmer is not what he makes from one enterprise but his payoff from the total farm organization (Kahlon et al., 1980). Based on this rationale the fanning systems research and extension methodolo-ies were developed. The new approach aims to increase overall farm productivity within the constraints and potentials of existing farming

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systems.The concept of farming systems research has rarely been applied to soil and water conservation (Stockincy, 1988). This approach was adopted for a sample of farmers ofDoon Valley to develop optimal plans to maximize their farm income and minimize the, soil loss

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occurring as a result of the various cultivation activities in which they were engaged. To bring farm and farmer in focus and to meet the twin objectives of production and protection, the study was undertaken.

Farming Systems Approach

Farming in small and medium holding situation is a complex and dynamic system. Farmes have evolved these over time in response to changing natural resource systems, socioeconomic conditions and environment. Majorities of factors that guide the selection of enterprises or farming systems are such that are not within the control of farmers. However. farmer tries to maximize pay-off from his total farm organization rather than from a single best enterprise. Therefore, resource allocations to differnt enterprises vary significantly on farmer's field from the optimum doses recommended by technical experts. To bridge this gap. the farmino' systems research and extension methodologies were developed. Hence a transition from crop system approach, aiming at location, farmer and environment specific recommendations, to farming systems approach covering the entire range of production activities engaged in by the farmer (crop husbandry, horticlture, animal husbandry, agriculture. etc.) took place in the early 1970's. The new approach aims to increase overall farm productivity within the constraints and potentials of existing farming situation. The approach is holistic in philosophy, multidisciplinary in nature and emphasizes understanding of the resource poor Third World farmer s aspirations, preferences, environment and constraints under which he has to operate (Dillon, 1987).

The farming systems research and extension methodologies were developed for contexts where either the farmers were resource-poor, or the possible productivity improvements from technolo;ical chanues were small, or both. Farming systems concepts were built on specific crop or animal agricultural technolo=ics, and social sciences were added to help transfer tcchnology. Because resource poor farmers often are at least partially subsistence producers. production, transformation and consumption operate at household level. The introduction of social science component into farming systems research shifted attention from technology transfer to identification oi th,' critical needs of farmers as clients (Bentley *et al., 1991).*

The farming systems appioach is now recognized by many as the only one that can identify and respond to the needs of limited resources farm families, especially those in marginal ecosystems. This approach to date has done more to change research objectives at national and international institutions than to change actual lariner practices. By legitimizing what limited resource farmers do and why they do it, a farming systems approach lends itself to policy analysis as well. Recent research in farming systems suggests that greater attention should he paid to exogenous variables, including policy and infrastrucre, as well as to development of technlolgy that really responds to the felt needs of limited resource farmres in improving their level ofliving (Flora, 1988).

Objectives

In the light of the above discussion, it is expected that suitable farming system approach will result in optimization of resources (through better mix of farm enterprises) and sustained production, and provide database for predictive models. Further, farm-level economic analysis is quite location specific and can provide to a farmer the information he needs to assess the economic rationale for adopting a particular farming system from amongst the available choice of farming systems. The specific objectives of the study are (i) to optimize land use, so as to efficiently utilize resources and meet community needs, (ii) to identify farming system options on scientific basis and (iii) to develop mathematical models, employing optimizing techniques.

II. DATA SOURCE AND ANALYTICAL FRAMEWORK

Data

The farms were categorized into two viz. small (between 1.0 and 2.0 ha) and medium (more than 2.0 ha) on the basis of land holding size. A total sample of 120 farmers, comprising of 60 farmers from each category from Dehradun district was surveyed. Resource base of each group was identified and the same is presented in Table 1. Returns over variable cost (ROVC) for each enterprise being taken by each group were worked out by subtracting total variable cost from gross revenues. Total variable cost incurred on each enterpriise was calculated by horizontal summation of all the cost except imputed value of family labour and rent for land. Gross revenue from ecach enterprise was obtatined by adding monetary value

Table 1. Resource Base of the Selected Farm Groups

Resources	Unit	Level at	
		Small	Medium
Total Operational Holding	Ha.	1.75	2.63
Irrigated Area	Per cent	17.8	25.6
Area Suitable for Agronomy Crops	Ha.	0.92	1.43
Area Suitable for Horticulture	Ha.	0.20	0.50
Averge Family Size	Nunbers	4.8	5.2
Available Work Force	Man day^{-1}	1.8	2.6
Cash in Hand During Kharif	Rs	5670	9801
Cash in Hand During Rabi	Rs	9817	12560
Average Number of Buffaloes	Nunbers	0.8	1.6
AverageNumber of Cows	Nunbers	0.6	0.8
Average of Bullock Pairs	Pairs	0.7	0.3

of main as well as by-product i. e. output x price. Synthetic farm situations were developed to depict input output coefficients for each enterprise under two farming situations. Improved technologies in the form of new varieties along with complete package of practices were also introduced in the respective farm situations.

The Central Soil and Water Conservation Research and Training Institute, Dehradun has been working in the development of technologies for conservation of soil and water in the region for last forty-five yerars. The crop production activities include in the model as well as taken by the farmers are common in the region. The farmer's practice is an integral part of each experiment (i. e. control) to judge the efficiency of improved technologies being developed at the research farm. The averages of past seven yerars soil loss data were considered in the model to estimate soil loss from various activities at farm level .

Model

Linear Programming (LP) occupies a premier position among optimization techniques in studies relating to resource use efficiency and enterprise combination. It is a powerful tool, which can efficiently handle a large number of linear constraints and activities, simultaneously, to provide precise results. The requirements of the farm family were categorized into two viz. maximization of farm income and minimization of soil loss. Linear programming technique was employed to maximize farm income and minimize soil loss with existing technology alone as well as existing and improved technologies together in the initial tableau. Farmers' preferences were taken into account in the form of minimum area and animal restrictions. An intermediate fodder production activity in thé form of *berseem* was also incorporated into the tableau. The data provided by the farmers were madel compatible to make it more meaningful.

The model for maximization of returns (over variable cost) or minimization of soil loss from the farm as a whole during a period of one year was as under.

Maximize Farm Income,

$$\pi = \sum_{j=1}^{n} r_j x_j^p - \sum_{t=1}^{4} (1+i) W_t x_t^l - \sum_{s=k.r} i x_s^c - (1+i) u x^{fp} - (1+i) v x^{fr}$$

or

Minimize Soil Loss,

$$\pi = \sum_{j=1}^{n} r_j x_j^p$$

Both subject to,

$\sum_{j=1}^{n} x_j^p \leq Lk$	*Kharif* Land
$\sum_{j=1}^{n} x_j^p \leq Lr$	Rabi Land
$\sum_{j=1}^{n} a_{ij}\, x_j^p - x_t^l \leq H_t$	Human Labour
$\sum_{j=1}^{n} a_j^k\, x_j^p - x_k^c \leq 0$	Kharif Capital
$\sum_{j=1}^{n} a_j^r\, x_j^p - x_r^c \leq 0$	Rabi Capital
$\sum_{t=1}^{4} w_t\, x_t^l + \sum_{s=k,r} x_s^c + ux^{fp} \leq k$	Capital Limit
$x_j^p \leq A_j$	Max, Area Restriction
$x_j^p \geq A_j$	Min. Area Restriction
$x_j^p = A_j$	Area Under j[th] Crop or Number of Animals Restriction
$-\sum_{j=1}^{n} f_j\, x_j^p - x^{fp} - x^{fr} + \sum_{j=1}^{n} gj\, x_j^p = 0$	Fodder Production Restriction
$x_j^p, x_t^l, x_s^c, x_f^p \geq 0$	Non-negativity Restrictions.

Where,

Activities :

x_j^p = j^{th} crop/livestock production activity

x_t^l = human labour hiring activity during t^{th} quarter

x_k^c, x_r^c = *Kharif* and *rabi* borrowing activities for working capital

x^{fp} = fooder purchase activity

x^{fr} = Winter fooder production (intermediate) activity.

Constrainsts :

$L_k\ L_r$ = hectares of *kharif* and *rabi* land available for crop production on farm

H_t = availability of family labour mandays on the farm during t^{th} quarter

K = amount of working capital used dsuring both the crop growing seasons in the existing/ optimum plan.

Coefficients :

r_j = returns per hectare/livestock unit over variable cost (Rs.) of or soil loss (t/ha) from j^{th} activity

w_t = wage per manday of human labour hired in t^{th} quarter (Rs)

i = rate of interest (per cent)

u = price for purchasing of fodder (Rs q^{-1})

v = cost of fooder produced (Rs ha^{-1})

a_{tj} = mandays of human labour required for the t^{th} quarter to produce one hectare of jth crop /to produce milk from one animal unit.

a_j^k, a_j^r = Rupees of working capital during kharif and rabi to take one hectare of j^{th} crop/ to rear one livestock unit.

f_j = quintals of foodder produced by jth activity.

g_j = quintals of fodder consumed by a milch animal.

It may be noted that the value of r_j coefficient in case of all rabi land activities, animal activities and all hiring/ purchasing activities was zero. In case of rabi crops, no erosion is observed in the area under study. Also, value of g_j coefficient for all activities other than animal activites are zero.

III. ANALYSIS OF RESULTS

The results of the study are grouped into two situations namely; small farm and medium farm, and they are presented in Table 2.

Small Farm Situation

Small farmers are receiving Rs 9,762 as income from 1.42 ha of land in a year. Their present farming system is generating 27.6 tonnes of soil loss per hectare per year which is very high. The cropping intensity in the present landuse system is 186 per cent. Maximum income that can be achieved with existing level of technology under this situation is Rs 13,515 which is about 38 per cent higher than present, with 200 per cent cropping intensity. But to achieve this, farmer will have to incur extra load of 0.6 t ha^{-1} yr^{-1} soil loss. Thus this plan may be acceptable in short run but inefficient from long- term point of view. The minimum soil loss that can be achieved with existing level of technology is 3.7 t ha^{-1} yr^{-1}. However, this plan will yield an income of only about Rs 3,000 per annum to the farm which may be not acceptable to the farmer.

After inclusion of improved technologies with the existing ones, the maximum farm income that can be achieved is Rs 23,010 which is 248 per cent higher than existing one. However, it would cause a soil loss to the turn of 13.3 t ha^{-1} yr^{-1} that is about 50 per cent less than that from use of existing technologies. The soil loss under this situation can be brought down to 3.7 t ha^{-1} yr^{-1} with a 30 per cent decrease in farm income. It is further evident from Table 2 that farm income with introduction of improved technologies is Rs 15,480 which is higher than existing resource use pattern. Therefore, it can be concluded that this pattern of resource use in small farming situation would be more profitable and sustainable than the one based on only existing technology.

Table 2. Farm Income, Soil Loss, Cropping Intensity and Environmental Pay off Under Different Farming Situations

Farming Situation	Technology Level	Objective	FI (Rs)	SL (t ha^{-1} yr^{-1})	CI (%)	Tradeoff (Rs t^{-1})
I. Small farm	a. Existing	Subsistence	9762	27.6	186	-
	b. - do -	Maximize farm income	13515	28.2	200	
						428
	c. - do -	Minimize soil loss	2999	3.7	144	
	d. a + improved	Maximize farm income	23010	13.3	186	
						781
	e. - do -	Minimize soil loss	15480	3.7	102	
II. Medium farm	a. Existing	Subsistence	16876	23.0	143	
	b. - do -	Maximize farm income	30624	28.16	200	
						580
	c. - do -	Minimize soil loss	16902	4.5	110	
	d. a + improved	Maximize farm income	35505	23.1	200	
						766
	e. - do -	Minimize soil loss	20786	3.9	110	

FI = Farm Income, SL = Soil Loss, CI = Cropping Intensity

Medium Farm Situation

This group of farmers is receiving Rs 16,876 annual farm income with 23 t of soil loss per ha per annum. Maximum income that can be achieved with existing level of technology for this farm situation is Rs 30, 624 but this optimal plan will result in soil loss to the tune of 28.16 t ha^{-1} yr^{-1} which is quite high. The minimum soil loss limit with this level of technology is 4.5 t ha^{-1} yr^{-1} with an annual farm income (Rs 16,902) almost equal to existing one. Though this is 45 per cent less than that when the objective is to maximize farm income, resource use pattern under plan II. c may find place in farmers field for posterity.

By blending of improved technologies with existing, the maximum income that can be achieved is Rs 35,505 with 200 per cent cropping intensity and 23.1 t soil loss which is more or less same as estimated in case of existing subsistence plan. This income was about Rs

Table 3. Existing and Optimal Farm Plans for Maximization of Returns Over Variable Cost (ROVC) and Minimization of Soil Loss Under Various Programming Situations for Small Sized Farms

Sl. No.	Crop/Animal Activity	Area (ha) Under Plan				
		I	II	III	IV	V
Kharif (Irrigated)						
1.	Paddy (Imp*)	0.10	0.22	-	-	-
2.	Paddy (Local)	0.22	0.10	0.10	-	0.100
3.	Paddy (Imp)	-	-	-	0.033	-
4.	Paddy (Local)	-	-	-	0.100	-
Kharif (Rainfed)						
5.	Maize (Imp)	0.10	1.00	-	-	-
6.	Maize (local)	0.80	0.10	0.10	-	0.100
7.	Maize (Local)	-	-	-	0.100	-
8.	Maize + Cowpea	-	-	-	1.000	-
Rabi (Irrigated)						
9.	Wheate (Imp)	0.32	0.32	0.12	-	-
10.	Wheat (Local)	-	-	0.20	-	-
11.	Wheat (Local)	-	-	-	0.167	-
12.	Berseem (Imp)	-	-	-	0.153	0.30
13.	Wheat (Imp)	-	-	-	-	0.02
Rabi (Rainfed)						
14.	Wheat (Imp)	0.20	0.70	0.90	-	-
15.	Wheat (Local)	0.50	0.20	-	-	-
16.	Mustard (Local)	0.20	0.20	0.20	-	-
17.	Wheat (Local)	-	-	-	0.033	0.200
18.	Mustard (Local)	-	-	-	1.066	0.200
19.	Wheat + Rai	-	-	-	-	0.537
Orchard						
20.	Papaya	0.20	-	-	-	-
Animal						
21.	Buffalo	0.8	1.0	1.0	1.0**	1.0
22.	Cow	0.6	1.0	1.0	1.0	1.0**

I = Existing farm plan

II = Optimal farm plan for maximization of ROVC with existing level of technology

III = Optimal farm plan for minimization of soil loss with existing level of technolgy

IV = Optimal farm plan for maximization of ROVC with existing and improved levels of technology

V = Optimal farm plan for minimization of soil loss with existing and improved levels of technology

* = Improved crop variety

** = Improved animal breed

5.000 more than that from only existing technology (plan II. b) and about Rs 18.700 more than that from the subsitence plan (plan II.a). The minimum soil loss that can be achieved by existing cum improved levle of technology is about 4 t ha^{-1} yr^{-1} with a farm income of Rs 20.786. It is significantly higher than that from optimal plans II. a and II. c though less than plans II. b and II. d as shown in Table 2.

Landuse Pattern

Landuse pattern under different farming and planning situations is presented in Tables 3 and 4 for small and medium farm groups respectively. Both the tables depict similar trends i. e. shifting of area under local varieties to improved ones. Improved package of practices are within the reach of both the farm groups with their existing resource level. Hence maximum possible area was allocated to them. Orchard crops did not find a place in any of the optimal plans even though suitable land was available for them.

IV. INFERENCE

From the foregoing analysis we conclude that (i) improved technologies have good potential for prospertiy with protection in both categories of farms (ii) reduction of soil loss with existing technology in small farm category is impractical while it is possible under medium farm group. (iii) in both farm groups maximization of farm income with existing technologies would, though yield an income higher than the existing one, but at a soil loss rate higher than the current one, (iv) maximization of farm income with increased level of technology would raise it to more than double the current income in both the farm groups; this in case of small farm groups would be achieved at a soil loss rate half the current one while in case of medium farm group would be achieved at the same rate of soil loss. (v) for both farm groups, minimization of soil loss with improved level of technology would reduce the loss to much below the tolerable limit in addition to providing an income which is Rs 5.718 and Rs 3,910 more than the current one for small and medium farm groups respectively. (vi) trade off between soil loss and farm income varies from Rs 428 to Rs 781 per tonne of soil loss. It is more in case of plans developed with improved package than with only existing, under both situations. Thus the study concludes that the present farming system is neither productive nor protective. Optimum use of farm resources and adoption of improved technology holds the key for eco-friendly sustainable development.

Table 4. Existing and Optimal Farm Plans for Maximization of Returns Over Variable Cost (ROVC) and Minimization of Soil Loss Under Various Programming Situations for Medium Sized Farms

Sl. No.	Crop/Animal Activity	Area (ha) Under Plan				
		I	II	III	IV	V
Kharif (Irrigated)						
1.	Paddy (Imp*)	0.10	0.570	-	-	-
2.	Paddy (Local)	0.50	0.100	0.100	0.100	-
3.	Paddy (Imp)	-	-	-	0.570	-
4.	Paddy (Local)	-	-	-	-	0.100
Kharif (Rainfed)						
5.	Maize (Imp)	0.005	1.160	-	-	-
6.	Maize (local)	0.8	0.100	0.100	-	-
7.	Toria (Local)	0.01	-	-	-	-
8.	Maize + (Local)	-	-	-	0.100	0.100
9.	Maize + Cowpea	-	-	-	1.160	-
Rabi (Irrigated)						
10.	Peas	0.005	-		-	-
11.	Wheat (Imp)	0.005	0.078	0.070	-	-
12.	Wheat (Local)	0.1	0.300	0.300	-	-
13.	Berseem (Imp)	-	0.292	0.300	0.207	0.300
14.	Wheat (Imp)	-	-	-	0.163	0.320
15.	Wheat (Local)	-	-	-	0.300	-
16.	Peas (Imp)	-	-	-	-	0.050
Rabi (Rainfed)						
17.	Wheat (Local)	0.60	-	-	-	-
18.	Wheat (Imp)	0.50	-	1.060	-	-
19.	Mustard (Local)	-	1.260	0.200	-	-
20.	Wheat + Rai	-	-	-	-	0.760
21.	Wheat (Local)	-	-	-	-	0.300
22.	Mustard (Local)	0.01	-	-	1.260	0.200
Orchard						
23.	Papaya	0.01	-	-	-	-
24.	Mango	0.01	-	-	-	-
25.	Litchi	0.01	-	-	-	-
Animal						
26.	Buffalo	1.6	2.0	2.0	2.0	2.0
27.	Cow	0.8	1.0	1.0	1.0	1.0

I = Existing farm plan
II = Optimal farm plan for maximization of ROVC with existing level of technology
III = Optimal farm plan for minimization of soil loss with existing level of technolgy
IV = Optimal farm plan for maximization of ROVC with existing and improved levels of technology
V = Optimal farm plan for minimization of soil loss with existing and improved levels of technology
* = Improved crop variety

REFERENCES

Bentley, W. R. (1991). "Social Science Research in Agroforestry and Other Landuse Technologies". in Burch et. al. (eds.), *Social Science Applications in Asian Agroforestry*. Winrock International, USA and Oxford & IBH Publishing Co. Pvt. Ltd, New Delhi.

Dillon, J. L. (1987). "Research and Technology Versus Hunger : Problems and Prospects". *New Zealalnd Agricultural Science*, **21:** 6-11.

Flora, C. B. (1988). "Farming Systems Approaches to International Technical Cooperation in Agriculture and Rural Life", *Forage Network in Ethiopia Newsletter*, **19:** 14-19.

Kahlon, A. S. and Karam Singh (1980): *Economics of Farm Management in India : Theory and Practice*, Allied Publishers Pvt. Ltd, New Delhi.

Stocking, M. A. (1988). "Assessing Vegetative Cover and Management Effects", in Ratan Lal (ed.), *Soil Erosion Research Methods*, SWCS and ISSS, Ankeny, Iowa 50021, USA