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Resource Use Efficiency Optimization of Major Farming Systems in Hills of Himachal Pradesh

Sanjeev Kumar and Ravinder Sharma[1]

Department of Economics and Sociology, Punjab Agricultural University, Ludhiana, Punjab-141 004, India
[1]Department of Social Sciences, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan-173 230, India
E-mail: sharmask93@rediffmail.com

***Abstract*:** Using primary data of 240 farmers, this study examines the resource use efficiency of predominant farming systems in the hills of Himachal Pradesh and optimizes the existing resource use using linear programming technique. Six predominant farming systems were identified in the study area and dairy was an important component in each farming system which indicates the importance of livestock in the study area. The study reveals the under-utilization of inputs in all farming systems. The optimization results indicate that there is a substantial scope for increasing per farm net income through an optimal use of the existing resources. The increase in the availability of binding resources can enhance the per farm net income of the farmers indicating the need to make scarce resources available to the hill farmers for increasing their income and improving livelihood security.

***Keywords*:** Agriculture, Farming system, Linear programming, Optimization, Optimal resource use

United Nations estimated that world population would increase from 7.7 billion in 2019 to more than 9.5 billion by 2050 and 10.9 billion in 2100 (UN 2019). So, to improve the world food security and meet out the increasing food demand, food production needs to rise by 50 per cent up to the year 2030 (UN 2008) and 70 per cent up to the year 2050 (FAO 2009, King et al 2017). Indian population is also expected to reach 1.6 billion by the year 2050 (Lehane 2014) and country would require about 349 million tonnes of food grains, 342.2 million tonnes of vegetables, and 305.3 million tonnes of fruits by 2050 (Singh 2019). However, the average size of land holdings in the country is very small and has declined to 1.08 ha in 2015-16 from 2.28 ha in 1970-71 (Agriculture Census 2015-16). If this trend continues, the average size of holding in India would further get reduced to 0.32 ha in 2030 (Khan et al 2015) and would be increasingly difficult to produce enough food for meeting the requirements of the growing population. Hence, the emphasis must be on increasing productivity levels besides diversification towards high-value crops (Economic Survey of India 2020-21). Since there is no further scope for horizontal expansion of land for cultivation of farm enterprises, the emphasis should be on vertical expansion by using the available resources optimally, increasing the yield per unit area, and choosing the best enterprise mix for improving the income level of the farmers (Sharma et al 2015, Kumar et al 2018a, Rao et al 2019). The farmers need to be assured of regular income for living at least above the poverty line because unless farmers' income increases significantly, distress cannot be tackled (Chand 2016). In this context, the farming system approach is one of the important solutions to achieve better growth in agriculture, ensuring food security, nutritional security, reduction in global poverty, improvement in living standards, and overall sustainable development of the society (National Commission on Farmers 2006). It is a holistic approach that boosts crop productivity, profitability and can meet the future demand for food without impairing the environmental and ecological balance (Sarvankumar et al 2020). Kumar et al (2022) revealed that providing short term trainings and field demonstrations related to different farming systems along with input subsidies to the farmers could enhance their income and standard of living. In this context, estimated the resource use efficiency of predominant farming systems practiced by the farmers in the hills of Himachal Pradesh which is one of the most progressive and popular hilly States of India. In present study, also optimized the existing resource use to work out the maximum attainable net returns to farmers from existing farming systems.

MATERIAL AND METHODS

This study makes use of primary data collected during the agricultural year 2018-19 using stratified multistage random sampling technique. The entire State of Himachal Pradesh has been divided into four agro-climatic zones whose elevation ranges from less than 650 to more than 2200 m amsl (GoHP 2013). The study area was stratified into four

strata as per these four agro-climatic zones of the state. Thereafter, one district with maximum cultivated area from each stratum, namely, Una district from Zone-I, Mandi district from Zone-II, Shimla district from Zone-III, and Kinnaur district from Zone-IV was selected. At the next stage, two blocks based on maximum cultivated area were selected from each selected district. Further, 3 gram panchayats from each block and 10 farmers from each gram panchayat were randomly selected. Thus, data were collected from 60 farmers from each district i.e., a total of 240 farmers using well designed pre-tested schedule.

Resource use efficiency: Cobb-Douglas production function was used to analyze the resource productivities of different farming systems in the study area.

$$Y = b_0 X_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4} X_5^{b5} X_6^{b6} X_7^{b7} u_i$$

Where, Y is gross farm income (Rs./farm), b_0 is the intercept, X_1 is the expenditure on human labour (Rs./farm), X_2 is the expenditure on machine labour (Rs/farm), X_3 is the expenditure on seeds/ planting material (Rs/farm), X_4 is the expenditure on manure & fertilizers (Rs /farm), X_5 is the expenditure on plant protection chemicals (Rs/farm), X_6 is the expenditure on feed and fodder (Rs /farm), b_is are the regression coefficients (production elasticity) with i= 1,2,……,6 and u_i is the random term. Other researchers also use similar methodologies to assess the resource use efficiency (Mesike et al 2009, Kumar et al 2018b, Kumar et al 2018c, Singh et al 2018, Sharma and Kumar 2019).

Returns to scale: The response on output (gross farm income) due to a proportionate change in inputs was estimated directly by the summation of regression coefficients (b_i). If the value of summation of 'b_i' is greater, equal, and less than unity, then there are increasing, constant and diminishing returns to scale, respectively (Gujarati et al 2012). The returns to scale were statistically tested using F-test (Rauf 2009).

$$F = \frac{\Sigma(b_i - 1)^2}{\frac{\text{Var } \Sigma b_i}{N-k}} \sim F(k-1),(N-k)df$$

Where, N is the number of sample observations, k is the total number of parameters estimated and Σb_i is the summation of elasticity coefficients.

Optimization of farming systems: Farming is a business activity in which the farm enterprises/components bear a complementary relationship with one another. In the present study, the optimum enterprises' combination of various crops and livestock under existing farming situations was estimated using the deterministic linear programming technique, developed by George B. Dantzig in 1947 (Dantzig and Thapa 1997). The present model bears a close resemblance to one used by Majeke and Majeke (2010), Mohamad and Said (2011), Andreea and Adrian (2012) and Patel et al (2015) for determining the optimal farm resources allocation and maximizing the total returns on the farm. The specification of the model is

$$\text{Maximize } Z = \sum_{j=1}^{n} C_j X_j$$

Subject to

$$\sum_{j=1}^{n} a_{ij} X_j \leq b_i \qquad \text{(Resource constraints)} \qquad (i = 1 \ldots\ldots m)$$

$X_j \geq 0$ (Non-negativity restriction) (j = 1…… n)

Where, Z is net returns from all crop and allied activities included in the model (Rs.), X_j is the level of the j^{th} activity in the model, C_j is the net returns per unit of j^{th} activity (Rs.), b_i is the total availability of i^{th} resource on the farm, a_{ij} is the total quantity/amount of i^{th} resource required per unit of j^{th} activity and n is the number of activities considered in the model. We maximized the annual net returns to owned resources subjected to various resource constraints, land, family labour, hired labour, farmyard manure (FYM), fertilizer requirements and working capital. Firstly, the optimization was done by fixing the availability of these resources equal to their existing use; and then by increasing the use of binding (scarce) resources by 20 per cent, except family labour. The binding resources are those which are fully consumed in a production process. In study fixed the on-farm requirement of farmers as, at least one standard animal unit (SAU) and 0.1 hectares of land under crops cultivation.

RESULTS AND DISCUSSION

The predominant farming systems were identified based on the number of farmers doing similar farming activities (Noorain 2010). The various components of farming systems included crops (cereals, pulses, and fodder crops), vegetables, fruits and dairy. Overall, six major farming systems were identified in the study area (Table 1), Crops + Vegetables + Fruits + Dairy (45% of the farmers), Crops + Fruits + Dairy (20%), Crops + Vegetables + Dairy (15%), Vegetables + Fruits + Dairy (10%), Crops + Dairy (8%) and Fruits + Dairy (2%), respectively. All farming systems have a dairy component which indicates the importance of livestock in the study area. In all the districts, the farmers practice Crops + Vegetables + Fruits + Dairy (C+V+F+D) and Crops + Fruits + Dairy (C+F+D) farming systems, although, C+V+F+D is predominant in Una (40%), Mandi (53%) and Shimla (45%) districts, and C+F+D is predominant in Kinnaur district. Vegetables + Fruits + Dairy (V+F+D) and Fruits + Dairy (F+D) farming systems were practiced by the farmers of Shimla (40%) and Kinnaur (8%) districts only.

Resource use efficiency of existing farming systems: The resource use efficiency was estimated by the Cobb-Douglas production function analysis at the overall level (Table 2) except for the F+D farming system, the reason being a few observations in this system. The significant F-value under all the farming systems indicates the better fit of the model. The model showed the positive and significant impact of human labour in C+V+F+D and C+V+D farming systems, manure and fertilizers in C+V+F+D, C+F+D and C+D farming systems, plant protection chemicals in V+F+D farming systems and feed and fodder in all the farming systems, indicating the sub-optimal use of these inputs, meaning that additional use of these inputs would increase the gross returns in the respective farming system. The overall significance suggests the need for additional application of labour, fertilizer management, judicial use of plant protection chemicals and additional feed and fodder to achieve higher gross returns. Mutoko et al (2013), Kumar et al (2018b) and Singh et al (2018) have also reported that farm revenue increases with additional application of fertilizers and labour use. The returns to scale in C+V+F+D (1.05), C+F+D (1.13) and C+D (1.15) farming systems indicate the need for increasing the input use in these farming systems to get more output, while in case of C+V+D (0.98) and V+F+D (0.88) farming systems, the farmers will lose efficiency if they increase the scale of production. These results are in correspondence with the findings of Mesike et al (2009) and Kasiime et al (2018).

Table 1. Existing farming systems in the study area

Farming systems	Proportion of farmers				
	Una (Zone-I)	Mandi (Zone-II)	Shimla (Zone-III)	Kinnaur (Zone-IV)	Overall
C+V+F+D	40 (24)	53 (32)	45 (27)	40 (24)	45 (108)
C+F+D	18 (11)	3 (2)	7 (4)	52 (31)	20 (48)
C+V+D	18 (11)	35 (21)	8 (5)	-	15 (36)
V+F+D	-	-	40 (24)	-	10 (24)
C+D	24 (14)	9 (5)	-	-	8 (19)
F+D	-	-	-	8 (5)	2 (5)
Total	100 (60)	100 (60)	100 (60)	100 (60)	100 (240)

C= Crops (Cereals, Pulses &Fodder crops), V= Vegetables, F= Fruits, D= Dairy
Figures in parentheses are the number of farmers practicing respective farming system

Table 2. Production function estimates for different farming systems in the study area

Independent variables	Regression coefficients				
	FS-I (C+V+F+D)	FS-II (C+F+D)	FS-III (C+V+D)	FS-IV (V+F+D)	FS-V (C+D)
Constant	0.747** (4.333)	0.363 (1.050)	0.839* (2.611)	4.308** (3.118)	0.367 (0.207)
Human labour	0.265** (5.075)	0.215 (1.939)	0.305* (2.358)	0.049 (0.132)	-0.075 (-0.160)
Machine labour	0.001 (0.264)	0.007 (0.782)	0.020 (1.734)	0.015 (1.027)	0.028 (0.898)
Seeds/ Planting material	0.039 (1.965)	0.016 (0.732)	0.104 (1.607)	-0.023 (-0.282)	0.013 (0.037)
Manure and fertilizers	0.396** (7.650)	0.348** (4..753)	-0.109 (-1.038)	-0.579 (-1.780)	0.488* (2.380)
Plant protection chemicals	0.013 (0.812)	0.020 (0.760)	0.113 (1.568)	0.782* (2.629)	-0.047 (-0.307)
Feed and fodder	0.337** (8.920)	0.519** (6.440)	0.551** (6.402)	0.636* (2.125)	0.739* (2.251)
Adjusted R^2	0.96	0.92	0.74	0.70	0.68
F-value	385.41**	91.92**	18.19**	9.95**	7.32**
Returns to scale	1.05**	1.13**	0.98**	0.88**	1.15**

Figures in the parentheses are t-values of respective variables
*, ** represent significance at 5% and 1% level of significance, respectively

Optimization of existing farming systems: The farmers in hilly regions of the country possess very limited resources particularly land, labour and capital. Therefore, the existing resource use under predominant farming systems have been optimized to maximize net farm income of the farmers (Table 3 to 7).

Optimization of Crops + Vegetables + Fruits + Dairy (C+V+F+D) farming system: The higher area allocation under vegetables (1.14 ha) followed by fruits (0.32 ha) and crops (0.10 ha), and rearing of 1.88 standard animal dairy units, would not only increase the farm income by 16.29 per cent compared to existing farm plan (Rs. 1,02,149), but also, decrease the use of hired labour, fertilizers and working capital by 56.12, 39.86 and 19.87 per cent, respectively (Table 3). There is scarcity of farmyard manure in the study area as it was fully used under the optimum farm plan. Therefore, if the availability of this scarce resource is increased by 20 per cent, then not only the farmers' income would increase by 30.17 per cent but the use of hired labour, fertilizers and working capital would also reduce compared to the existing farm plan.

Optimization of Crops + Fruits + Dairy (C+F+D) farming system: The farmers receive per farm annual net income of Rs. 88,137 under exiting C+F+D farming system (Table 4). If the existing resource use is optimized, the farmers would receive an increase of Rs. 687 by allocating more area under fruits (0.60 ha) as compared to area under crops (0.10 ha) and rearing 3.73 standard animal units, simultaneously. There would be reduction in the use of family labour from 284.84 to 265.92 man days, farmyard manure from 126.05 to 121.38 quintal and fertilizer from Rs.5863 to Rs. 5682. The results show the scarcity of hired labour and working capital in C+F+D farming system. The increased availability of these resources has the potential to increase the farmers' income by 5.79 per cent compared to income under the existing plan by allocating 0.75 hectare area under fruits, 0.10 hectare area under crops and rearing of 3.72 standard animal units on a farm.

Table 3. Optimum farm plan for C+V+F+D farming system in the study area

Particulars		Existing farm plan	Optimum farm plans with	
			Existing resource use	20% Increased resource use
Area (ha)	Crops	0.82	0.10	0.10
	Vegetables	0.13	1.14	0.80
	Fruits	0.61	0.32	0.66
Dairy (SAU)		3.42	1.88	2.24
Family labour (MD)		339.18	339.18	339.18
Hired labour (MD)		107.81	47.13	87.47
Farmyard manure (Qtl)		143.88	143.88	172.66
Fertilizers (Rs)		7325	4405	6922
Working capital (Rs)		99508	79735	85686
Income (Rs)		102149	118791	132967

Table 4. Optimum farm plan for C+F+D farming system in the study area

Particulars		Existing farm plan	Optimum farm plans with	
			Existing resource use	20% Increased resource use
Area (ha)	Crops	0.29	0.10	0.10
	Fruits	0.58	0.60	0.75
Dairy (SAU)		3.66	3.73	3.72
Family labour (MD)		284.84	265.92	284.84
Hired labour (MD)		75.06	75.06	78.44
Farmyard manure (Qtl)		126.05	121.38	125.24
Fertilizers (Rs)		5863	5682	5863
Working capital (Rs)		94104	94104	101776
Income (Rs)		88137	88824	93237

Optimization of Crops + Vegetables + Dairy (C+V+D) farming system: The optimization of existing resource use in C+V+D farming system (Table 5) results in an increase of Rs 11,056 in per farm net income (Rs 41546) compared to existing farm plan (Rs 30,490). Also, there is reduction in the use of family labour, hired labour and expenditure on fertilizer after allocating more area under vegetables (0.33 ha) compared to crops (0.10). There is scarcity of farmyard manure and working capital in C+V+D farming system and increased in availability of these resources has a potential to not only increase the per farm annual net income by 57.64 per cent but also reduce the use of hired labour and fertilizers as compared to the existing farm plan. This would require an allocation of 0.40 hectare under vegetables, 0.10 hectare area under crops and rearing of 3.15 standard animal units on a farm, simultaneously.

Optimization of Vegetables + Fruits + Dairy (V+F+D) farming system: Optimization of V+F+D farming system reveals that all the available resources are optimally used by the farmers as income in existing farm plan and optimum farm plan under existing resource use is same (Rs 8,491) (Table 6). All the resources are scarce under this system and increase in their availability would increase the farmers' income by 6 per cent after allocating more area under fruits (0.48 ha) as compared to vegetables (0.17 ha) and rearing 3.56 standard animal units on a farm, simultaneously.

Optimization of Crops + Dairy (C+D) farming system: The farmers under C+D farming system were also using the available resources optimally (Table 7). The optimization under increased resource availability indicates an increase of 10.44 per cent in per farm net income and less use of hired labour, farmyard manure and expenditure on fertilizers as compared to the existing farm plan. The results related to optimization of farming systems revealed that reallocation of available resources not only increased the income of the farmers but also reduced the use of some of the inputs. These results are consistent with the results of Noorain (2010), Kumar et al (2018a) and Nientao et al (2019).

Table 5. Optimum farm plan for C+V+D farming system in the study area

Particulars		Existing farm plan	Optimum farm plans with	
			Existing resource use	20% Increased resource use
Area (ha)	Crops	0.60	0.10	0.10
	Vegetables	0.09	0.33	0.40
Dairy (SAU)		3.20	2.99	3.15
Family labour (MD)		275.39	250.44	275.39
Hired labour (MD)		9.89	1.65	1.65
Farmyard manure (Qtl)		38.18	38.18	45.82
Fertilizers (Rs)		1350	310	330
Working capital (Rs)		80050	80050	86844
Income (Rs)		30490	41546	48064

Table 6. Optimum farm plan for V+F+D farming system in the study area

Particulars		Existing farm plan	Optimum farm plans with	
			Existing resource use	20% Increased resource use
Area (ha)	Vegetables	0.26	0.26	0.17
	Fruits	0.39	0.39	0.48
Dairy (SAU)		3.57	3.57	3.56
Family labour (MD)		289.41	289.41	289.41
Hired labour (MD)		40.42	40.42	47.94
Farmyard manure (Qtl)		95.38	95.38	110.48
Fertilizers (Rs)		4239	4239	5086
Working capital (Rs)		90050	90050	90465
Income (Rs)		85491	85491	90621

Table 7. Optimum farm plan for C+D farming system in the study area

Particulars	Existing farm plan	Optimum farm plans with	
		Existing resource use	20% Increased resource use
Area (ha)/ Crops	0.40	0.40	0.10
Dairy (SAU)	3.34	3.34	4.11
Family labour (MD)	258.34	258.34	258.34
Hired labour (MD)	2.11	2.11	0.53
Farmyard manure (Qtl)	23.00	23.00	5.75
Fertilizers (Rs)	971	971	243
Working capital (Rs)	79757	79757	93165
Income (Rs)	29121	29121	32162

CONCLUSIONS

Due to wide range of agro-climatic conditions, the farmers living in the hills of Himachal Pradesh practice six predominant farming systems for their food and nutritional security, namely, Crops + Vegetables + Fruits + Dairy (C+V+F+D), Crops + Fruits + Dairy (C+F+D), Crops + Vegetables + Dairy (C+V+D), Vegetables + Fruits + Dairy (V+F+D), Crops + Dairy (C+D) and Fruits + Dairy (F+D). The study indicates the under-utilization of inputs under all farming systems, meaning that opportunities still exists to increase the gross farm income by additional use of these inputs. The optimum farm plans developed for different systems reveal the possibilities to increase farm profitability by utilizing available resources optimally and following optimum-mix of different farm components. The farmers would get higher returns if they allocate more area under fruits and vegetables as compared to crops. Although, dairy is an important component of all farming systems, but there is resource scarcity of farmyard manure in the study area. Therefore, in addition to the State government's innovative schemes to provide subsidy for the purchase of '*desi*' cows, the government needs to extensively promote the use of vermiculture, forest leaf litter, farm waste, bio fertilizers and green manure in the fields which would help to improve the soil fertility and land productivity. The study clearly reveals the possibility of increasing the farm income if the availability of scarce resources is increased under all the existing farming systems. Further, the capital deficiency in the study area indicates the need to provide more capital to the hill farmers, so that they can increase the input use on their farms for generating more income and improving their living standards.

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