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Agriculture production systems, farm characteristics and managerial interventions for improved resource use efficiency in dry temperate Lahaul valley of Himachal Pradesh

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Abstract
Agriculture is the pre-dominant occupation of the inhabitants of tribal Lahaul valley in Himachal Pradesh. It has peculiar land use with traditional coarse grain based cropping patterns to commercial cultivation of pea, potato and vegetable crops. This area has shown its promise through spectacular economic growth over the year which was mainly due to the advent and adoption of commercial farming by its entre preneuring inhabitants. The present study therefore was made to examine the land use, input-output relationships and resource use efficiency for different farm categories as it is likely to help policy planners in formulating restructuring plans for equitable growth. A two-state stratified random sampling design was adopted to select the sample. In all 70 small, 50 medium and 30 large farms were selected. The input –output relationship was studied through log linear production function estimated directly using the input-output data from individual farms. Increasing returns to scale were observed on small farms but decreasing returns were observed on medium and large farms. For the farm as a whole the ratios suggested that priority should be extended towards human labour as compared to all other variables.

Keywords: Tribal agriculture, input output relationship, returns to scale, resource use efficiency

Introduction
The tribal areas in Himachal Pradesh form about 42 per cent of the total geographical area of the state. Kinnaur, Lahaul-Spiti and parts of Chamba, Kullu and Kangra districts of Himachal Pradesh are the abodes of tribal community. Agriculture is the pre-dominant occupation of the tribes in different parts of the State [1]. The studied area has very difficult terrain with ice fields, snow-covered peaks and most inhospitable climate. The region is cut-off from the rest of the world for more than six months in a year. The sole access to Lahaul valley is over the 3,915 meters high Rohtang Pass. Tunnel construction below Rohtang for year round accessibility is in full swing and is likely to be opened by the end of year 2019.
The primary source of economy is agriculture. But from almost September to April, the studied area of Lahaul valley receives heavy snowfall. The soil is sandy and has stones and boulders at places. The cultivation is done in narrow strips of land. The entire cultivated land is irrigated (100%) as most of the precipitation is in the form of snow that too during winter months. Agricultural operations begin in April and ends in September. Night soils and animal dungs are generally used as manure. Only in Pattan Valley, two crops are raised. In some cases snow has to be melted by throwing earth over it, if it does not melt by the time agricultural operations begin. Conventionally inferior millets, wheat, buckwheat, barley are also grown by the tribes. The crops like potato, pea, hops, *kuth* and pea have greater potential. Apple is also fast adopted by the farmers.
Due to the peculiarities of tribal economy, it is important to understand land use, input-output relationship and the resource use efficiency of farm production so as to help policy planners in formulating restructuring plans and accordingly reorient their extension efforts [2, 3]. It is also likely to help in reorganizing the farms so as to maximize the profits. Therefore the objectives were to examine the characteristics of land use and to understand the input-output relationship and resource use efficiency for different farm categories.

Materials and Methods
A two-state stratified random sampling design was adopted to select the sample. In the first stage of sampling, 10 per cent of the inhabited villages (20 in number) were selected.

A complete list of all the cultivators in the selected villages was prepared along with their land holdings. The farmers were categorized into small, medium and large farms through cumulative cube root frequency method. The farm categories were made into small farms with land holding size upto 1.6 ha, medium farms with land holding size from 1.6 to 2.4 ha and large farms with land holding size more than 2.4 ha. In the second stage of sampling, 150 farmers were selected through proportional allocation method. In all 70 small, 50 medium and 30 large farms were selected.

The input-output relationship was studied through production function estimated directly using the input-output data from individual farms. The following log linear production functions was used for the estimation of input-output relationship.

$$Y= aX_1^{b1}+X_2^{b2}+X_3^{b3}+X_4^{b4}+X_5^{b5}+X_6^{b6}+X_7^{b7}+e^u$$

That is

$$Logy= loga+ b_1logX_1+ b_2logX_2+b_3logX_3+b_4logX_4+b_5logX_5+b_6logX_6+b_7logX_7+u$$

Where,
Y = Crop output in rupees
X_1=Human labour in rupees
X_2=Bullock labour in rupees
X_3=Expenditure on seeds in rupees
X_4=Expenditure on fertilizers and manures in rupees
X_5=Expenditure on irrigation in rupees
X_6=Expenditure on plant-protection measure in rupees
X_7=Management index
e=Error term;
a=Intercept, and;
b_1s=Elasticity coefficients.

Crop output (Y) reflects total value in rupees of the total output of farm including the byproducts. The total farm income was calculated by converting the output of all crops into value terms by multiplying the yields of different crops with their respective prices and adding them up.

Human labour (X_1) was examined by taking man-days employed on the farm as an explanatory variable. It includes family labour, permanent and casually hired labour and was measured in terms of man-hours employed during the year.

Expenditure on seeds (X_3) was calculated by multiplying the current market prices of seeds to total quantity used. The values were calculated for the total seeds used whether home produced or purchased.

Expenditure on fertilizers and manures (X_4) was considered an explanatory variable. The value of manures (local one) was calculated by giving the values prevailing in the particular village. In general grass and organic manures are exchanged between the needy farmers.

Expenditure on Irrigation (X_5) was used as a proxy for the extent of irrigation during the year as 100 per cent of the studied area is irrigated, but the intensity of irrigation use was likely to be different on different farms. So the expenditure on irrigation was taken as variable.

Expenditure on Plant Protection Measures (X_6) was used as this expenditure is likely to affect crop output and its use is likely to be more on large farms. The cost incurred was taken as an important explanatory variable.

Management Index (X_7) was prepared on the basis of decisions regarding various operations which were identified as management factors. These decisions were timely sowing of crops, applying fertilizers at proper time and proper doses, use of proper doses of FYM, irrigating crops at proper time, use of pesticides at proper time and proper doses, grading and proper marketing. These attributes were assigned weights on the basis of judgment of the subject matter specialists. The different weights were assigned to the individual respondents' feedback and the decisions were ranked. These ranks were converted into scores using `Fisher and Yates' table which normalizes the scores based on ranks. A weighted sum of these scores for each farmer was used as a Management Index.

Adjusted coefficient of Multiple Determination (R^{-2})
It was calculated to assess the explanatory power of the production function. The formula used was

$$R^2_{adj} = 1 - \left[\frac{(1-R^2)(n-1)}{n-k-1}\right]$$

Where R^2 = Sample R^2
N= number of observations
K= number of independent variables/ parameters

Returns to Scale
The sum of elasticity coefficients indicated the returns to scale and was calculated as ∑bi where b_is represent regression coefficients. The values may be equal to one, greater than 1 or less than one indicating thereby constant returns, increasing returns and decreasing returns to scale respectively. The sum of elasticity coefficients (bi) was statistically tested by F test.

Marginal Value Productivity (MVP)
It was calculated as follows

$$\mathbf{MVP\ (X_i) = \frac{Y}{Xi}\, bi}$$

Where
MVP (X_i) = Marginal Value Productivity of X_i
X_i = Value of the i^{th} input at its geometric mean levels
Y= Value of the i^{th} output at its geometric mean levels
It interprets for a particular resource the expected addition to the gross value caused by an addition of one unit of that resource while other inputs are held constant. The reliable estimates of MVPs were found by keeping the variables at geometric mean levels.

MVP – Factor Cost Ratios
These ratios were calculated to know how much of a particular input could use profitably and to determine the input-output ratios. These were obtained through division of the marginal value productivity of each input with its factor cost. But since, in our case all explanatory variables were in rupees farm, so the MVP's and MVP – factor cost ratios of different inputs remained the same.

Comparison of Productivities between two Groups
The MVPs of same resource for different enterprises can be

compared by the estimation of the elasticity coefficients necessary for i^{th} resources which would result in the marginal product in the j^{th} situation equal to the marginal product of that resource in the k^{th} situation i.e.

$$bij\frac{Yi}{Xij} = bik\frac{Yk}{Xij}$$

$$bij = \frac{YYk - Xijk}{XijYj + Xik}$$

The positive difference between the actual elasticity of resource X_i in situation j, elasticity (b_{ij}) and estimated elasticity ($b_{ij}^{/}$) required to equate its marginal productivity of resource X_i would be higher in situation `k' is against which the test was made.

Both primary and secondary data were used for the present study. The primary date were collected on pre-tested schedules and questionnaires by personal interview method, whereas, secondary data were collected from different government offices. Data refers to the agriculture year 2014-15.

Results and Discussion

Agriculture forms single crop cultivation for most of the area. From September to early April, Lahaul valley remains under snow and the rainfall usually is very small and of very short duration. Generally there are few heavy showers in the months of July and August.

Land use

The agricultural operations begin in April and have to be completed till September every year. Ploughing of the fields is done by *Churu* which is a cross between cow and yak. Female labour plays an important role in performing agricultural operations. Ploughing is usually done once as soils are sandy, shallow and has stones and boulders at places. Night soils and animal dung are generally used as manure. Soon after the harvesting of summer crops in September, fields are ploughed before the snowfall begins. As the snow melts in April/May, the surface of the fields is stirred up with a rake hoe and the seed is sown. It is the Pattan valley where the cropping intensity is more than hundred per cent. Irrigation to the crops is done through gravity channels known as *kuhls.* Water from natural resources like springs is carried through channels (*kuhls*) to the desired place.

Wheat, maize, barley and millets are grown. Kuth, potato, pea, vegetable production and hops are the main cash crops of the area. The roots of *kuth* are used for medicine and perfumes. Potato has significant role with recorded highest yield in the world. Area under pea cultivation has increased over the years. Vegetable production is now fast adopted by the farmers. The productivity of maize, wheat, barley, pea and potato is competitive with the state productivity levels and is observed to be 18.35, 10.27, 11.63, 117.46 and 146.61 qtls per hectare as per the annual season and crop report [4]. The climate change is proving beneficial for the area as apple belt is shifting from traditional apple growing areas of the state to this wet and dry temperate area. As a result apple cultivation is gaining momentum in the recent years.

Operational holding

On an average, the holding size is 1.85 hectares. However, the variation within the farms was much more. In case of small farms, the average holding size was 0.85 hectare as compared to 1.96 hectares and 4.04 hectares on medium and large farms respectively. There was no leasing-in or leasing-out practice in the sample households. The uncultivated area was about 0.04 hectare. The per capita land was 0.25 hectare. The per capita land was 0.14 hectares on small farms, 0.25 hectare on medium farm and 0.56hectare on large farms respectively.

Problems faced by the Farmers

The major problems are low use of fertilizers, less availability of FYM, non-availability of HYV seeds, poor crop management and short labour availability. It was reported that non availability of farm inputs (fertilizers, seeds, plant protection chemicals etc) is most crucial problem faced by the farmers. This problem was more severe on small farms followed by the medium and large farmers. The untimely supply of farm inputs was another reported problem. The scarcity of human labour and weak extension support system were other problems. Lower market prices were also reported.

Production functions for the farm as a whole

The multiple log-linear regression model was estimated with all the seven explanatory variables viz., human labour, bullock labour, expenditure on seeds, expenditure on manures and fertilizers, expenditure on irrigation, expenditure on plant protection measures and management index. The non-significant variables were dropped and the model was rerun. The results so obtained are given in the table 1. The elasticity values (b_{is}) associated with the independent variables indicate percentage change in the dependent variable with one per cent change in the particular independent variable keeping all other variables constant at their geometric mean levels. The adjusted co-efficient of multiple determination (R^2_{adj}) indicates the extent of variations explained by the independent variables taken together.

The study of table 1 shows that in case all-farm situation only three variables. i.e. expenditure on fertilizers and manures (X_4), expenditure on plant protection manures (X_6) and management index (X_7) were statistically significant. The total explained variations were 73.50 per cent. On small farms except bullock labour (X_2) all other variables were statistically significant. All elasticity coefficients are positively related to farm income. However, on medium farms, human labour (X_1), and expenditure on plant protection measures (X_6) and management index (X_7) were statistically significant. The total explained variations were 67.70 per cent. The case of large farms bullock labour (X_2) and expenditure on seeds (X_3) were found statistically non-significant. The remaining five variables constituted for 76.50 per cent of total variations. In case of small farmers, the total explained variations were 75.10 per cent.

The magnitude of elasticity of human labour was found to be highest for large farm situation followed by medium and small farms. This suggests that small farms were more labour intensive. Labour available on medium and large farms was not sufficient due to large operational holdings. The elasticity coefficient for expenditure on seeds (X_3) was significant on small farms only. The comparative poor financial position and limited access to resources have resulted in productivity for this particular variable. Similar is the case with expenditure on fertilizers and manures, expenditure on plant protection measures, and management indeed.

The sum of elasticity coefficients was greater than one on small and large farms thereby, showing increasing returns to scale. On medium and all farm situations, the sum of elasticity coefficients was less than one, thereby depicting decreasing returns to scale.

Table 1: Cobb Douglas production function for farm income in Lahaul valley of Himachal Pradesh

Variables/ Particulars	Small	Medium	Large	All farm
a	1.2230	1.6350	1.3971	1.2235
X_1	0.1823* (0.0650)	0.3456* (0.1250)	0.3561** (0.1305)	-
X_2	-	-	-	-
X_3	0.2350* (0.1123)	-	-	-
X_4	-	-	0.2628** (0.0913)	0.2842* (0.1352)
X_5	0.4423* (0.2132)	-	0.1672* (0.0412)	-
X_6	0.3741* (0.1355)	0.3220* (0.1246)	0.3340* (0.1375)	0.2425* (0.1110)
X_7	0.2410* (0.1110)	0.2460* (0.1105)	0.3525* (0.1605)	0.3247* (0.1402)
R^2	0.7510*	0.6770*	0.7650*	0.7350*
∑bi	1.4747*	0.9136	1.4721	0.8514

Note: Figures in parentheses are standard errors
**Significant at 1 per cent probability level
*Significant at 5 per cent psrobability level

Resource-use efficiency

So as to see the allocative efficiency of agricultural resources on different crops under different farm situations, comparison of Marginal Value Products (MVPs) of inputs factors was made. The marginal value productivity to factor cost ratio remained the same since MVPs were in rupees value. The MVPs of various inputs were computed at their geometric mean levels. The Management Index (X_7) was deleted as the cost of this variable was not quantifiable.

For the farm as a whole the ratios suggested that priority should be extended towards human labour (X_1) as compared to all other variables (Table 2). It was the most profitable variable on all farm situations. Investment should be diverted towards human labour followed by expenditure on fertilizers and manures (X_4) and expenditure on plant protection measures (X_6). On small farms again the preference should be given to human labour (X_1). For other variables the ratios were almost similar however the investment pattern should be expenditure on seeds (X_3), expenditure on plant protection measures (X_6) and expenditure on irrigation (X_5). In case of medium farms, it is profitable to invest only on human labour (X_1) and expenditure on plant protection measures (X_6). However the preference should be extended to human labour(X_1). On large farms investment on human labour (X_1) should be preferred followed by expenditure on plant protection measures (X_6), expenditure on irrigation(X_5) and expenditure on fertilizers (X_4). For the farm as whole, the returns were high for the variables human labour and expenditure on plant protection.

Table 2: Marginal value products and resource use efficiency of factor inputs for farm income of Lahaul valley in Himachal Pradesh

Variables/ Particulars	Marginal Value Productivity and Factor Cost Ratios			
	Small	Medium	Large	All farms
X_1	6.3361**	9.4523**	9.7250**	7.2361*
X_2	-	-	-	-
X_3	2.4710*	-	-	-
X_4	-	-	1.4350*	1.3130*
X_5	2.2347*	-	1.7225*	-
X_6	2.5434*	2.2831*	3.6123*	1.8109*

**Significant at 1 per cent probability level
*Significant at 5 per cent probability level

Comparison of resource productivities

On comparison of small and medium farms, the MVPs of human labour (X_1) and management index (X_7) were found to be higher on medium farms. However for variable X_6 that is expenditure on plant protection measures, the marginal productivity was higher on small farms.

In case of small and large farm comparisons, the MVPs of human labour (X_1) and management index (X_7) were higher on large farms as is indicated by the statistically significant negative difference. For other variables the difference was statistically positive implying thereby that marginal value productivities for expenditure on fertilizers and manures (X_4), expenditure on irrigation (X_5) and expenditure on plant protection measures (X_6) were higher on small farms. However in case of medium and large farms, the MVPs for human labour (X_1), expenditure on plant protection measures (X_6) and Management Index (x_7) were higher on large farms.

Table 3: Comparison of productivities of different resources in farm income amongst different farm categories

Variable	Small and Medium			Small and Large			Medium and Large		
	b_{ij}	b_{ij}^1	b_{ij}- b_{ij}^1	b_{ij}	b_{ij}^1	b_{ij}- b_{ij}^1	b_{ij}	b_{ij}^1	b_{ij}- b_{ij}^1
X_1	0.1823	0.3724	-0.1901*	0.1823	0.3965	-0.2142**	0.3456	0.3985	-0.0529*
X_2	-	-	-	-	-	-	-	-	-
X_3	-	-	-	-	-	-	-	-	-
X_4	-	-	-	0.4246	0.2425	0.1821**	-	-	-
X_5	-	-	-	0.4423	0.1424	0.2999**			
X_6	0.3741	0.3031	0.0710*	0.3741	0.2930	0.0811*	0.3220	0.3748	-0.0528*
X_7	0.2410	0.2527	-0.0117*	0.2410	0.3825	-0.1415	0.2460	0.3679	-0.1219*

** Significant at 1 per cent probability level
* Significant at 5 per cent probability level

Conclusion

The results of production function suggested that small farms were more labour intensive. Labour available on medium and large farms was not sufficient due to large operational holdings. Increasing returns to scale were observed on small and large farms but decreasing returns were observed on medium farms. For the farm as a whole the ratios suggested that priority should be extended towards human labour as compared to all other variables. It was the most profitable variable on all farm situations. Investment should be diverted towards human labour followed by expenditure on fertilizers and manures and expenditure on plant protection measures. The non-availability and untimely supply of required quantity of farm inputs (fertilizers, seeds, plant protection chemicals etc) is crucial problem faced by the farmers. This problem was more severe on small farms followed by the medium and large farmers. The scarcity of human labour and weak extension support system needs to be effectively intervened.

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