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ENHANCING THE LIVELIHOOD SECURITY THROUGH HYBRID RICE CULTIVATION IN TRIBAL AREA OF UTTARAKHAND: AN APPLICATION OF LINEAR PROGRAMMING APPROACH

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Abstract- Farm level data were used to analyze the impact of hybrid rice (PA 6444) cultivation for livelihood security and income enhancement on tribal farm households in community development block Kalsi of Dehradun district of Uttarakhand. 89 tribal farmers were selected randomly for finding cost and return of rice varieties, farm income inequality and optimum crop plan. CACP costs concept (Commission for Agricultural Costs and Prices) and linear programming model (LINDO compute based software) were used for calculating costs and returns and to develop optimal crop combination for tribal farmers respectively. Gini-coefficient was used for finding farm income inequality. Gross return and net returns per hectare were found highest in hybrid rice than other varieties. Per rupee invested was also highest which was ₹1.74. LP model suggested that hybrid rice (PA 6444) and pant dhan-12 were feasible in tribal area and net return was increased about 121%. Gini-coefficient indicated farm income equality in year 2012-13 was more in comparison to year 2013-14 when hybrid rice was introduced in this year on the tribal farm. This study shows more area should be allocated under hybrid rice cultivation so that income of tribal farmers can be increase for ensuring their livelihood security and reduce the farm income inequality.

Keywords- Hybrid rice, livelihood security, CACP concepts, linear programming, gini-coefficient

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Introduction

Paddy cultivation is the most important agricultural operation in the country, not only in terms of food security, but also in crating better livelihoods, opportunities for rural population. The area under rice in 2012-13 was 42.86 million hectare with production of 105 million tones and productivity of 2462 kg per hectare. It constitutes 25% to agricultural gross domestic product [1]. Rice is the main staple food of 60 per cent of the total population while paddy is cultivated only 33 per cent of the total cultivated area of India. In terms of area under paddy, India ranks first but in terms of production of paddy China ranks first in the world.

Hybrid rice has the potential to significantly increase rice yields from 15-30% relative to local and high yielding varieties, which leads to higher production, farm income, and stabilize prices of rice at food-insecure tribal households. Despite these promising results, adoption of hybrid rice cultivation in India has been low in comparison with China where over a half of all rice area is under hybrid rice.The area under hybrid rice in India was 2.50 million hectare with yield 48 quintals per hectare in 2013 [2].The need for such an increase is reflected in efforts to increase the acreage under the hybrid rice which is lag behind in yield. The farm level experiences have shown significant yield advantage of hybrid rice over the best High Yielding Varieties of rice. The adoption of hybrid rice is still at a lower level [3].

Hybrid rice may contribute to address India's serious food security concerns. Many challenges are faced by tribal population due to land and water scarcity and pressure on natural resources in India. The technological innovation in agricultural production plays pivotal role in ensuring food security in the tribal area. Therefore, tribes need to find new varieties for their survival. Indian agricultural scientists have introduced a number of hybrid varieties of rice in the last two decades. In tribal has not adopted hybrid varieties, it would have faced food crisis in future. The ICAR, New Delhi launched Tribal Sub Plan for upliftment of tribal people and enhancement of farm income for their livelihood security. Hybrid rice cultivation is one of the components of it. Long time food security for tribal population can be ensured if hybrid varieties are popularized in the state and allocate their limited land under hybrid rice for income enhancement. Kaur. *et al* successfully formulated an LP model to suggest the optimal cropping pattern for maximizing net returns and ensuring significant savings of ground water with the aim of sustaining groundwater use in Punjab [4].

Keeping in view of the above facts this study was conducted to find cost and returns of hybrid rice over the traditional varieties, develop optimum plan for tribal farmers using linear programming and gini-coefficient for farm income inequality..

Materials and Methods

The objective of this study is to find cost and return of rice varieties, farm income inequality and optimum plan for livelihood security and income enhancement of tribal farmers. The present study was carried out in Kalsi block of the Dehradun district of Uttarakhand. A team of scientists conducted intensive survey to identify villages and farmers for implementation of hybrid rice technology. Out of 87 villages of Kalsi 3 villages (Haripur, Vyasbhud and Vyasnahri) were selected randomly. Out of three villages, 30 farmers were selected from two villages randomly and from one village 29 farmers selected randomly to make total of 89 farmers for the study. The present study used a comparison of the conditions of the tribal farm household of the hybrid rice technology programme in pre and post hybrid rice technology period. The difference in pre and post hybrid rice technology period was analyzed.

I. The CACP (Commission for Agricultural Costs and Prices) concepts were used for calculating costs and returns of major rice varieties and hybrid rice on selected tribal farm fields [5]. CACP cost concept is given below:

Cost A1 = Total working capital or all variable costs excluding family labour cost and including land revenue, depreciation and interest on working capital.

Cost A2 = Cost A1 + rent paid for leased-in land.

Cost B1 = Cost A1 + interest on the value of owned fixed capital assets (excluding land).

Cost B2 = Cost B1 + rental value of owned land (Net of land revenue).

Cost C1 = Cost B1 + imputed value of family labour.

Cost C2 = Cost B2 + imputed value of family labour.

Cost C2* = Cost C2 estimated by taking into account statutory minimum or actual wage rate, whichever is higher.

Cost D = Cost C2* + 10 per cent of cost C2* on account of managerial function performed by farmer.

II. Prime importance of tribal farmers is whether rice varieties production combination is optimal? Does it yield maximum net returns? For this problem linear Programming (LINDO computer based software) model was used to find optimum plan for allocation of cultivated land of tribal farmers among different rice varieties in Kharif season (June to October) so that profit would be maximized. Linear programming formulation is given below:

Formulation of objective function-

a. Maximization of net profit (Z): Allocate cultivated land to all the rice varieties so that net profit maximize. Thus, the objective function is as follows:

$$Z \qquad Max \sum_{j=1}^{c} NP_j \; X_j \qquad \text{.....1}$$

Formulation of constraints-

C_1. Availability of cultivable land: The allocation of land to all the rice varieties in the Kharif season must not exceed total cultivable land. This imposes the constraint as;

$$\sum_{j=1}^{c} X_j \leq L \qquad \text{.....2}$$

C_2. Labor requirement: Number of labors required per hectare rice cultivation should be less than the total number of labours available throughout Kharif season.

$$\sum_{j=1}^{c} W_j X_j \leq W \qquad \text{..... 3}$$

C_3. Bullock/Machine hours requirement: The total number of machine hours required for various rice varieties should not exceed the total machine-hours available in the Kharif season.

$$\sum_{j=1}^{c} MH_j \; X_j \leq TMH \qquad \text{..... 4}$$

C_4. Cost of pesticides and fertilizers: The regular doses of pesticides and fertilizers are required to get maximum yield from the rice varieties. The cost of it imposes constraints as follows.

$$\sum_{j=1}^{c} CPF_j \; X_j \leq TAPF \qquad \text{..... 5}$$

C_5. Constraint on seed cost: Every farmer do not compromise with the quality of the seed and hence they do not bother about the expenditure on the seed. The cost of seed constraint as follows.

$$\sum_{j=1}^{c} SC_j \; X_j \leq TAS \qquad \text{.....6}$$

C_6. Upper/lower boundaries for area under the crop: Minimum area allocated under rice varieties for food requirement of the tribal families is also a constraint due to its taste and preferences.

$$X_j \geq L \qquad \text{.....7}$$

Non-negativity constraint

$$X_j \geq 0 \qquad \text{..... 8}$$

Where,

j=1.....c = No. of rice varieties for cultivation

X_j = Area of land used for cultivation of different rice varieties (ha)

Z = Total profit from growing different rice varieties (₹)

NP_j = Net profit per hectare for rice varieties (₹)

L = Available total land (ha)

W_j = Requirements of labor per hectare for rice varieties (man days)

W = Expected total laboure available in the Kharif season (man days)

MH_j = Average bullock/machine hours per hectare for rice varieties (hours)

TMH = Expected total bullock/machine hours available (hours)

CPF_j = Cost of pesticides and fertilizers per hectare for rice varieties (₹)

TAPF = Expected total amount of pesticides and fertilizer available (₹)

SC_j = Cost of seed as per hectare (₹)

TAS = Expected total amount of seed (in ₹) available

The goals of the objective function are to maximize farm income by rice varieties grown by the tribal farmers at the end of the kharif season and livelihood security for family subject to land, labor, human and bullock labour used, cost of pesticides, fertilizer and seed constraints. [Table-1] represents the LP matrix. The Right Hand Side (RHS) represents the constraints on the resources.

The average land holding size of tribal farm household in the study was 0.05 hectares. Labor and bullock & machine hour's availability per household for cultivation of rice was 120 man days and 80 hours respectively. Total working capital availability for pesticides & fertilizers and seed were ₹2500 and ₹2000 respectively. The farmers were interested to maximize their net returns from allocation of land among rice varieties in the kharif season.

The LP model is given below:

Objective function

Maximize Z = 45913X1+25979X2+7145X3+28095X4+25587X5+3905X6

Subject to:

1 X1 +1 X2+1 X3+1 X4 +1 X5 +1 X6 <=0.5 *(Land constraints in ha)*

69 X1 + 76 X2+ 76 X3+75 X4 + 75 X5 +74 X6 <= 120 *(Labour constraints in days/ha)*

16.83 X1 + 16.94 X2+17.83 X3+17.93 X4+ 16.64 X5+16.85 X6 <= 80 *(Bullock and machine labour constraint in hours)*

2562X1+2355X2 +2657X3+2317X4+2026X5+2055X6 <= 2500 *(Cost of pesticide & fertilizer constraint in ₹/ha)*

4896X1+572X2+656X3 +604X4+2847 X5+591X6 <= 2000 *(Cost of seed constraint in ₹/ha)*

III. Lorenz curve and Gini-coefficient can be used to measure the inequality of farm income. The Lorenz Curve relates the cumulative proportion of income to the cumulative proportion of population. The shape of the Lorenz Curve is an indicator of how much inequality in income distribution and gini-coefficient was calculated as the ratio of the area between the Lorenz curve and equality line, divided over the total area under the 45° line [6].

Gini = Concentration (A) / Maximum concentration area (A+B)

Result and Discussion

Rice occupies the most important place in the agricultural sector and state economy of Uttarakhand. Hybrid rice (PA 6444) cultivation was introduced in

tribal. dominated villages of Kalsi block of district Dehradun during 2013-14. Hybrid rice is new for tribal farmer so that training of technical know-how and critical farm input was given to farmer for successful cultivation of hybrid rice

Costs and returns for rice varieties grown by the tribal farmers

Tribal farmers used resources in production of rice varieties, which was owned and purchased or hired in different proportions. The allocation of area under rice varieties by farmer depends on level of production and net profit generated per unit area. Hence, the study of costs and returns is important in determining the level of profit and identifying the relative profitability of the rice varieties grown by the farmers.

Table-1 *Linear programming matrix*

Rice varieties / Particulars	Hybrid rice	Pant dhan-4	Pant dhan-11	Pant dhan-12	Basmati	Local variety	Resource limit
	X1	X2	X3	X4	X5	X6	
Land (ha)	0.04	0.08	0.16	0.08	0.08	0.08	0.5
Labor (man days/ha)	69	76	76	75	75	74	120
Bullock & machine labor	16.83	16.94	17.83	17.93	16.64	16.85	80
Cost of pesticide & fertilizer (₹/ha)	2562	2355	2657	2317	2026	2055	2500
Cost of seed (₹/ha)	4896	572	656	604	2847	591	2000
Net profit (₹)	**45913**	**25979**	**7145**	**28095**	**25587**	**3905**	

Table-2 *Computation for total cost and gross return for rice variety* *(₹/ha)*

Particulars	Hybrid rice (PA 6444)	Pant dhan-4	Pant dhan-11	Pant dhan-12	Basmati	Local variety
A. Operational cost						
Family labor	10000 *(19.95)*	10000 *(21.69)*	12000 *(25.72)*	12000 *(25.25)*	14000 *(29.09)*	13000 *(28.13)*
Hired labor	3987 *(7.95)*	4800 *(10.41)*	2781 *(5.96)*	3009 *(6.33)*	1077 *(2.24)*	2062 *(4.46)*
Bullock labor	5791*(11.55)*	6500 (14.10)	3750 *(8.04)*	4766 *(10.03)*	5245 *(10.90)*	5460 *(11.82)*
Machine charges	3048*(6.08)*	2394 *(5.19)*	5375 *(11.52)*	4652 *(9.79)*	3491 (7.25)	3390 *(7.34)*
B. Material cost						
Seed	4896*(9.77)*	572 *(1.24)*	656 *(1.41)*	604 *(1.27)*	2847 (5.92)	591 *(1.28)*
Manure	257*(0.51)*	--	--	697 *(1.47)*	--	243 *(0.53)*
Fertilizer	2094*(4.18)*	1874 *(4.07)*	2267 *(4.86)*	2013 *(4.24)*	1658 *(3.45)*	1866 *(4.04)*
Plant protection chemicals	468*(0.93)*	481 *(1.04)*	391 *(0.84)*	305 *(0.64)*	368 (0.76)	189 *(0.41)*
Irrigation charges	388*(0.77)*	388 *(0.84)*	388 *(0.83)*	388 *(0.82)*	388 *(0.81)*	388 *(0.84)*
C. Other cost						
Interest on working capital @ 9%	471*(0.94)*	383 *(0.83)*	351 *(0.75)*	370 *(0.78)*	339 *(0.70)*	319 (0.69)
Depreciation cost	241*(0.48)*	225 *(0.49)*	221 *(0.47)*	234 *(0.49)*	227 *(0.47)*	224 *(0.48)*
Interest on owned fixed capital asset	246*(0.49)*	229 (0.50)	225 *(0.48)*	241 *(0.51)*	235 (0.49)	229 *(0.50)*
Rental value of land	18250 *(36.40)*	18250 (39.59)	18250 *(39.12)*	18250 *(38.40)*	18250 *(37.92)*	18250 (39.49)
Total cost	**50137 *(100)***	**46096 *(100)***	**46655 *(100)***	**47529 *(100)***	**48125 *(100)***	**46211 (100)**
Yield of MP (00'Kg/ha)	69.24	46.5	35	49.16	32.72	32.94
Yield of BP(00'Kg/ha)	95.00	69.75	48	68	50	40
Selling price of MP (₹00'Kg)	1250	1400	1400	1400	2100	1400
Selling price of BP (₹00'Kg)	100	100	100	100	100	100
Gross Returns	96050	72075	53800	75624	73712	50116
Net returns	45913	25979	7145	28095	25587	3905
Range of TC	42515-54769	42976-50425	44829-47873	44645-48780	41693-47941	43045-49826
SD of TC	1972	1882	1532	1328	2027	5871
Range of GR	72544-105468	48125-78400	66500-80500	48000-79333	49000-112000	32200-50750
SD of GR	8435	8822	7073	9415	20592	4031

Note: Figures in parentheses indicate percentage to total cost, MP- main product, BP- by product, TC- total cost, SD- standard deviation, GR- gross return

The total cost of cultivation of rice was divided into operational, material and other cost. In the operational cost major share was family labor among all the rice varieties grown by tribal farmers. It was highest in basmati rice (29.09%). It reflects unemployment and hence dependency of tribal people on agriculture. Hired labor, bullock labor and machine hours were further important part of operational cost. Seed constituted the major share in material cost. It was highest in hybrid rice (9.77%) followed by basmati rice (5.92%) due to its higher market price. In case of hybrid rice though, seed was distributed to the tribal farmers by the university free of cost to popularize hybrid rice cultivation in the area, but still it was one of the major items of the total cost. A perusal of the table further reveals that fertilizer, plant protection chemicals and irrigation were other important components of material cost. Rental value of land was also major proportion of the total cost. The yield of hybrid rice was highest (6924 kg/ha) than other rice varieties grown in the tribal area. Gross returns and net returns per hectare were also found highest in hybrid rice i.e. ₹96050 and ₹45913 respectively, whereas in local varieties it was found lowest i.e. ₹3905.

Costs and returns based on CACP costs concept was used to know that actual costs and returns realized by the farmers are depicted in [Table-3]. It includes managerial costs for managing the cultivation of rice and it was imputed value. Cost D in Hybrid rice (PA 6444), Pant dhan-4, Pant dhan-11, Pant dhan-12, Basmati and Local variety were ₹55149, ₹50705, ₹51320, ₹52281, ₹52938 and ₹ 50833 per hectare respectively. Net returns over cost D were found highest in hybrid rice ₹40901. Per rupee invested were also found highest in hybrid rice as 1.74 indicating that there was ₹0.74 net profits for every one-rupee investment in hybrid rice cultivation in the study area. Thus, study showed that cultivation of hybrid rice was most profitable in comparison to other rice varieties grown in tribal farms.

Table-3 *Computation for costs and return based on CACP for rice variety.* *(₹/ha)*

Particulars	Hybrid rice (PA 6444)	Pant dhan-4	Pant dhan-11	Pant dhan-12	Basmati	Local variety
Cost A1*	21639 *(39.24)*	17616 *(34.74)*	16180 *(31.53)*	17037 *(32.59)*	15640 *(29.54)*	14732 *(28.98)*
Cost B1	21885 *(39.68)*	17845 *(35.19)*	16405 *(31.97)*	17278 *(33.05)*	15875 *(29.99)*	14962 *(29.43)*
Cost B2	40135 *(72.78)*	36095 *(71.19)*	34655 *(67.53)*	35528 *(67.96)*	34125 *(64.46)*	33212 *(65.34)*
Cost C1	31885 *(57.82)*	27845 *(54.92)*	28405 *(55.35)*	29278 *(56.00)*	29875 *(56.43)*	27962 *(55.01)*
Cost C2**	50135 *(90.91)*	46095 *(90.91)*	46655 *(90.91)*	47528 *(90.91)*	48125 *(90.91)*	46212 *(90.91)*
Cost D	55149 *(100)*	50705 *(100)*	51320 *(100)*	52281 *(100)*	52938 *(100)*	50833 *(100)*
Net return over						
Cost A1	74411	54459	37620	58587	58072	35384
Cost A2	74411	54459	37620	58587	58072	35384
Cost B1	74165	54230	37395	58346	57837	35154
Cost B2	55915	35980	19145	40096	39587	16904
Cost C1	64165	44230	25395	46346	43837	22154
Cost C2	45915	25980	7145	28096	25587	3904
Cost C2*	45915	25979	7145	28096	25587	3904
Cost D	40901	21370	2480	23343	20774	-717
Per rupee invested	**1.74**	**1.42**	**1.05**	**1.45**	**1.39**	**0.99**
Unit cost of main product, cost C2 (₹/Q)	**654**	**895**	**1204**	**873**	**1328**	**1267**

*Cost A1 and Cost A2 are equal due to absence of leased in land in the study area,**Cost C2 and Cost C2* are equal due to statutory minimum and actual wage rate are same in the study area.

Hence hybrid rice cultivation should be promoted among tribal farmers because its yield was found highest as compared to high yielding rice varieties and traditionally grown rice varieties grown by the tribal farmers. Due to this increased production of hybrid rice farm income of tribal was furthermore increased and hence ensuring their livelihood security.

Linear programming formulation for Kharif season (2013-14)

Linear programming (LP) is a useful method for describing and analyzing tribal farm livelihood systems. Crop planning involves choices of rice varieties with fixed land availability in the tribal farms.

Comparison of existing and optimum crop plan

The existing and optimum land allocation plan of tribal farmers is presented in [Table-4]. The results that we obtain from using the LP model yield a net return of ₹ 21097 as compared to ₹9552 obtained by using traditional methods (existing plan) of land allocation. The difference in the net return is 121%. In existing plan area under hybrid rice (PA 6444), Pant dhan-4, Pant dhan-11, Pant dhan-12, basmati and local varieties were 0.04, 0.08, 0.14, 0.08, 0.08 and 0.08 hectare respectively whereas all the area in optimum plan came under hybrid rice (PA 6444) and pant dhan-12 with 0.39 and 0.11 hectare respectively and other varieties were not feasible in tribal area. Land allocation plan obtained by using linear programming yields more return than from traditional methods. The solution from the LP model suggests that the farmer should use LP for making decisions of land allocation in order to make more return. Traditional methods do not guarantee optimal strategies.

Table-4 *Results of linear programming model*

Particulars	Variables	Existing	Optimum	% increase over existing plan
Hybrid rice (PA 6444)	X1	0.04	0.39	875.0
Pant dhan-4	X2	0.08	-	-
Pant dhan-11	X3	0.14	-	-
Pant dhan-12	X4	0.08	0.11	37.50
Basmati	X5	0.08	-	-
Local	X6	0.08	-	-
Net returns (Rs./ha)		**9522.10**	**21096.65**	**121.55**
Land (ha)		0.50	0.50	-
Production (Kg)		2058	3252	58.01

Farm income distribution

The farm income distribution was showed by Lorenz Curve. In the figure 1, the Lorenz curve of farm income of 2013-14 was near to line of equality which indicates inequality of income lesser as compared to previous year (2012-13). The Gini-coefficient further indicated the extent of inequality in farm income distribution.

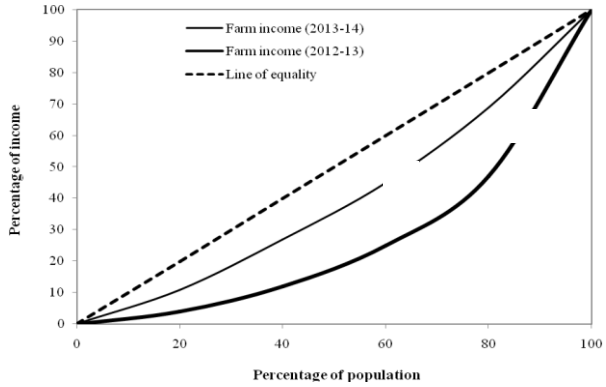

Fig-1 Lorenz curve of farm income for households

It was 0.68 in 2013-14, which was less as compared to 0.74 in year 2012-13 [Fig.-1] due to introduction of hybrid rice in tribal areas which stabilized farm income due to more production with less cost. Hybrid rice is now popular among tribal farmers to strengthen food security of small and marginal tribal farmers.

Conclusion

In this paper, costs and returns of rice varieties grown by the tribal famers were work out and also their livelihood system was modeled with LP. Gross returns and net returns per hectare were also found highest in hybrid rice i.e. ₹96050 and ₹ 45913 respectively. Per rupee invested was 1.74, which was also highest in hybrid rice. The LP model developed solves the problem of how to select a combination of rice varieties that is feasible given a set of fixed constraints and that maximizes return while achieving other goals such as food security. Comparison of results obtained by existing plan and LP model reveal that results obtained from the LP model are more superior. The Gini-coefficient indicated extent of inequality in farm income distribution in year 2012-13 was more than 2013-14. Thus in order to maximize income in tribal farms of the study area should increase the cultivation hybrid rice (PA-6444) for ensuring their food security.

Conflict of Interest: None declared

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