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Increasing Income and Employment through Sustainable Farming Systems in Water Scarce Region of Uttar Pradesh

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Abstract

The farming systems in the water-scarce region of semiarid Uttar Pradesh have been examined. The availability of land and also of water has become the most limiting factors in farming for increasing the levels of farm income and employment. Therefore, an effort has been made to suggest sustainable farming systems through optimization of farm resources and also by putting restriction on the availability of irrigation water. It has been shown that the income and employment could be increased in the water-scarce situation if the farm resources are utilized optimally and less water-requiring crops/ activities are selected in the farm plan.

Introduction

To have sustainable livelihood security and improve the standard of living, the farm families need to generate additional income in a sustainable manner from the available farm resources. A shift is needed from the prevalent cereal-based farming system to a diversified commercialized farming system. The availability of land and also of water has become the most limiting factors in farming for increasing the levels of income and employment (Kumar and Jain, 2002). The farmers, particularly small and marginal, need to be encouraged to produce suitable high-value crops. As pressure builds on water, the bigger farmers often dig deeper, even usurping

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water from the nearby wells of small farmers. At local levels, small farmers are already struggling for their existence, often leading to skirmishes among farmers (Gulati, 2001). Besides policy agenda for better management of irrigation water through pricing reforms for both surface and groundwater, and involving user groups, especially small farmers, in water management, there is a need to evolve profitable and sustainable farming systems using less water for irrigation. It is essential that farmers be guided about profitability and impact of the existing system on degradation of natural resources, particularly soil and water. In view of the expanding demand for water for non-agricultural purposes, water will become the most scarce resource in future. Thus, judicious use of land and water will be central to the growth of agriculture and livestock. Fast decline in the groundwater table is constraining agricultural production and productivity also in the southwestern semi-arid (SWSA) zone of Uttar Pradesh. In this back drop, the paper has explored the potential of increasing income and employment by optimizing the farming systems with and without restrictions for irrigation water in the Mathura district of SWSA zone of Uttar Pradesh.

Numerous alternative production opportunities such as common field crops, high-value crops and livestock enterprises exist and compete for available limited farm resources. Due to uncertainty in the productivity performance of crops, farmers generally tend to diversify their product-mix and also to minimize the risk of total failure of a particular crop (Jha, 1994). However, in their anxiety to enhance the risk-bearing ability, the farm families practise over-diversification of the enterprise-mix in their farm. But the farms in potato-based farming systems in the study area were highly specialized in the potato crop, irrespective of the farm size, and are continuously increasing the acreage under potato crop, in spite of huge losses in potato production during most of these years. On the other hand, the groundwater table in the study area has been declining rapidly, to the extent of 1.02 m per year (Anonymous, 1992-96). This problem is attributed to the wrong policies of water and electricity pricing and excess use of water by the farmers (Chadha, 2003). The continuous decline in groundwater is indicative of its non-judicious and inefficient use for irrigation. However, this hypothesis needs to be tested empirically. The problem of depletion of groundwater in the potato-based farming system of the study area has been compounded as large farmers have gone for deep bore-wells of more than 200 feet depth, that makes the groundwater unavailable in the shallow tube-wells of small farmers. The existing cropping pattern may have to be adjusted in favour of crops requiring comparatively less water. However, to convince the farmers, there is a need to find out optimal farm enterprise-mix that maximizes farmers' income under water-scarcity areas.

Data and Methodology

The study was conducted in the Mathura district representing the southwestern semi-arid zone of the Uttar Pradesh state. The secondary information regarding structure and access to irrigation, cropping pattern, milk production and agro-climatic conditions of the 12 development blocks of the district was collected. Consequently, two blocks, viz. Farah and Sadabad were purposively selected to represent the diverse water-scarce farming situations in the district. Farah block had wheat-mustard dominance with livestock including goats, and the other block, Sadabad, had mixed farming situation with majority of the area devoted to potato cultivation. Two villages from each selected development block were selected randomly. A complete enumeration of the households in the selected villages was carried out. The preliminary information was collected from all the households on total landholdings, cropping patterns, livestock inventory, and major source of income. In addition, factors like soil type, quality and availability of irrigation water, availability of credit, and infrastructure like, cold storage, input delivery system, transport and marketing facilities were also considered for classifying the households of selected villages into various farming system groups. The farming system groups so identified were: (i) Wheat-mustard based farming system group, and (ii) Potato-based farming system group. Finally, a sample of 113 households from these farming system groups was selected on the basis of probability proportional to the size in each farming system group. The selected farmers were post-stratified into farm-size groups namely, category I (up to 2 ha) and category II (> 2 ha).

Model

The optimal farming systems for both the categories were developed using programming models (Agrawal and Heady, 1972; Zionts, 1974). The linear programming model was extended to incorporate the integer values of livestock enterprises, while rest of the activities were taken as non-integer in the optimum solutions. Recognizing the difficulty in working out the optimum plans for each of the selected farm household individually, the resource-use data and input-output coefficients of the selected respondents under different farming systems and farm-size categories were pooled and averaged for each category of the farm to develop synthetic farm situation. The sensitivity analysis was also carried out to determine the effect of change in the total water availability for irrigation on optimum farming systems. The water restrictions were imposed in both potato-based and wheat-mustard-based farming systems. The requirement of irrigation water was estimated for the optimum farm plan. Consequently, alternative optimum plans were obtained by artificially reducing the total water availability for irrigation by 10, and 20 per cent. The optimum plans I, II, III, and IV developed for wheat-mustard-based and potato-based farming systems indicated the optimum plan with capital borrowing activity, optimum plan with artificially reduced supply of irrigation water by 10 per cent, optimum plan with reduced supply of irrigation water by 20 per cent, and optimum plan with goat enterprise (without water restriction), respectively. It was assumed that the farmers had been using available irrigation water timely considering the critical stages of plant growth. The goat-rearing activity was introduced only in category I, as only some of the small farmers in the study area were practising it.

The activities and constraints used in the programming can be summarized through the following equations:

$$\text{Maximize } Z = \sum_{j=1}^{n} C_j X_j + \sum_{i=1}^{k} C_i X_i$$

$$- P_{LM} \sum_{m=1}^{12} l_m - I_{CS} \sum_{S=1}^{2} C_S - P_t T_L - P_S S_P$$

subject to the following resource and non-resource constraints:

$$\sum_{j=1}^{n} a_{ej} X_j \le A_e$$ (Land constraints) e = 1, 2, 3, 4

$$\sum_{j} l_{jm} X_j + \sum_{i} l_{im} X_i - l_m \le L_m$$ (Labour constraint)

$$\sum_{j} C_{js} X_j + \sum_{i} C_{is} X_i + \sum_{s} C_{LS} F_L + \sum_{m} P_{lm} l_m + \sum_{s} I_{CS} C_S + P_S S_P - C_S \le C_w$$

(Working capital constraint)

$$\sum_{i} t_x X_i - T_L \le T$$ (Medium-term capital constraint)

$$\sum_{j} S_{jr} X_j - \sum_{i} S_{ir} X_i + S_P = 0$$ (Integration of crop and livestock enterprises with fodder)

$$X_{j/i} \le Z_{j/i}$$ (Maxima restriction)

$$X_{j/i} \ge M_{j/i}$$ (Minima restriction)

$$\sum_{j} W_{jg} X_j \le W_g$$ (Water restriction)

where,

C_j = Net returns to fixed factors per unit of crop activity (Rs)

C_i = Net returns to fixed factors per unit of livestock activity (Rs)

P_{LM} = Average daily wage of hired labour (Rs)

I_{CS} = Interest on working capital for six months (Rs)

P_t = Interest on medium-term capital per annum (Rs)

P_S = Average purchase price of one quintal straw (Rs)

X_j = Level of the j^{th} crop activity (acres)

X_i = Level of the i^{th} livestock activity (number)

l_m = Amount of hired labour in the m^{th} month (man-days)

C_S = Amount of borrowed working capital in *kharif*/*rabi* seasons (Rs)

T_L = Amount of borrowed medium-term capital required for purchasing of livestock (Rs)

S_P = Amount of dry straw purchased (quintals)

a_{ej} = Area of land (acre) used for one unit of j^{th} crop activity in respective land category 'e'

A_e = Total land availability in respective land category 'e' (in acres)

l_{jm} = Amount of labour used in the m^{th} month by one acre of the j^{th} crop activity

l_{im} = Amount of labour used in the m^{th} month by the i^{th} livestock activity

L_m = Amount of family labour available (man-days) in the m^{th} month

C_{js} = Amount of working capital used by one unit of crop activity in the s^{th} season (*kharif*/*rabi*)

C_{is} = Amount of working capital used by one unit of livestock activity in the s^{th} season (*kharif*/*rabi*)

C_W = Amount of working capital available in *kharif*/*rabi* season

t_x = Market value of the i^{th} livestock activity (Rs)

T = Market value of milch animals (Rs)

S_{jr} = Amount of fodder produced (quintals) per unit of crop activity

S_{ir} = Annual consumption of fodder (quintals) per unit of livestock activity

$Z_{j/i}$ = Maximum possible acreage/number under the j^{th} crop and the i^{th} livestock activity

$M_{j/i}$ = Minimum acreage/number under the j^{th} crop and the i^{th} livestock activity

W_{jg} = Amount of water (in mm acre) used per unit of the j^{th} crop activity, and

W_g = Total water (mm acre) available per annum for the g^{th} farming system.

Results and Discussion

Characteristics of Farming Systems

Among the wheat-mustard-based and potato-based farming systems, wide variations were observed in the source and magnitude of households' income. The former was the most prominent system in the district. Of the total 785 households covered for complete enumeration in the 4 villages, 68.53 per cent of the households belonged to wheat-mustard-based farming system group, having loam to sandy loam soils and groundwater as the source of irrigation, which was declining fast. Moreover, the groundwater in Farah block having wheat-mustard-based farming system was slightly saline in nature. The potato-based farming system in the area consisted of sandy loam soils and irrigation was available through tube-wells. There also existed cold storage facility with a capacity of around two million tonnes in and around the district. Apparently, the farmers of potato-growing area had relatively higher level of awareness and commercial orientation. The average number of years of schooling of the head of the household was comparatively higher (9 years) in the potato-based farming system. The contribution of potato crop towards the households' gross income was highest, accounting for around 78 per cent of the total income, followed by the dairy enterprise, which contributed hardly 5 per cent.

Optimal Enterprise-mix under Different Farming Systems

Wheat-mustard-based Farming System

The enterprise-mix presently followed on both small and large farms got changed in the optimum farm plans (Table 1). The number of livestock activities decreased, only relatively profitable activity of milch buffalo entered into the optimum plan and its number increased in both the categories. Pigeon-pea, fodder sorghum, wheat, and fodder berseem had occupied more area, and barley had less area in the optimal plan as compared to the existing level. However, the reduction in the supply of irrigation water in optimal plans II and III resulted in the shifting of the cropped area from wheat to mustard crop on small farms, and wheat to barley and mustard on large farms. But, the area under pigeon pea, and fodder sorghum and the number of milch buffaloes remained at increased level. A unit of 10 goats was found profitable to be included in the plan IV. The cropping intensity in the optimum plans on small farms increased from 147 per cent to 200 per cent and in the case of large farms, it was 172-174 per cent as against 157 per cent in the existing situation. It was also reflected that the livestock enterprise,

Table 1. Optimum combination of enterprises under wheat-mustard-based farming system, per farm

Particulars	Category I					Category II			
		Optimum					Optimum		
	Existing	I	II	III	IV	Existing	I	II	III
Crop enterprises (acre)									
Wheat	1.61(28.96)	1.98(26.19)	1.65(21.83)	1.31(17.33)	1.98(26.19)	4.85(30.41)	5.08(28.93)	3.40(19.36)	2.00(11.47)
Mustard irrigated	1.40(25.18)	1.00(13.23)	1.33(17.59)	1.67(22.09)	1.00(13.23)	3.55(22.26)	3.24(18.45)	3.24(18.45)	2.00(11.47)
Mustard unirrigated	0.27(4.85)	0.65(8.60)	0.65(8.60)	0.65(8.60)	0.65(8.60)	1.37(8.59)	1.37(7.80)	1.37(7.80)	1.37(7.86)
Barley	0.18(3.24)	-	-	-	-	-	-	1.68(8.56)	2.96(16.98)
Bajra	1.46(26.26)	1.88(24.87)	1.88(24.87)	1.88(24.87)	1.88(24.87)	4.34(27.20)	3.50(19.93)	3.50(19.93)	3.50(20.08)
Pigeon pea	0.03(0.54)	1.00(13.23)	1.00(13.23)	1.00(13.23)	1.00(13.23)	-	1.50(8.54)	1.50(8.54)	1.37(7.86)
Moong (green gram)	-	-	-	-	-	0.06(0.38)	0.80(4.56)	0.80(4.56)	0.80(4.59)
Fodder sorghum	0.49(8.81)	0.90(11.90)	0.90(11.90)	0.90(11.90)	0.90(11.90)	1.46(9.15)	1.65(9.40)	1.65(9.40)	1.65(9.47)
Fodder *berseem*	0.12(2.16)	0.15(1.98)	0.15(1.98)	0.15(1.98)	0.15(1.98)	0.32(2.01)	0.42(2.39)	0.42(2.39)	0.42(2.41)
Total cropped area	5.56(100)	7.56(100)	7.56(100)	7.56(100)	7.56(100)	15.95(100)	17.56(100)	17.56(100)	17.43(100)
Cropping intensity (%)	147	200	200	200	200	157.76	173.69	173.69	172.40
Livestock enterprises									
Buffalo	2.17	4.00	4.00	4.00	4.00	3.46	5.00	5.00	5.00
Local cow	0.21	-	-	-	-	0.21	-	-	-
Goat	-	-	-	-	10	-	-	-	-
Draught animal	0.42	-	-	-	-	0.43	-	-	-
Returns to fixed farm resources (Rs /annum)	38693	55429	54985	54541	62015	89785	112199	109756	106423

Note: Figures within the parentheses indicate percentages to total cropped area especially buffalo- and goat-rearing could be an effective diversification strategy even under water-scarce farming situations.

Potato-based Farming System

A perusal of optimum plans (Table 2) revealed that potato remained the most important crop of the system on both the categories of farms. However, the land-use pattern required some significant changes in the existing plan in order to maximize the farm returns. The area under potato decreased marginally on small farms and increased on large farms. The average returns from potato on small farms were comparatively low. This was mainly because of lower productivity and inability of the small farmers to sell their produce at the right time and at the right place in the face of wide fluctuations in prices. In summer crops, the cropped area shifted from cucurbits and sunflower to chillies and brinjal. The average productivity of sunflower was generally low because of the damage of crop due to inconsistent and untimely rains (pre-monsoon showers). The number of milch buffaloes also increased in the optimum plans and so also the area under fodder crops of sorghum and *berseem*. As a result of imposition of water restrictions in plans II and III, the total cropped area and cropping intensity decreased marginally as compared to those in plan I. The decrease in area was mainly observed in the case of chillies, cucurbits and brinjal vegetable crops. These crops required comparatively more water. The area under mustard, and fodder sorghum and *berseem* remained at an increased level as in plan I and hence the number of buffaloes also remained the same in the alternative plans. This again underlined the importance of livestock under water-scarce farming situations. The livestock had great ability to adjust under water-scarcity without much affecting the farm income. Fodder for livestock if needed might be imported from the fodder-surplus areas during the critical periods.

Levels of Farm Income and Employment under Different Optimal Farming Systems

The income and employment generated under different farming systems in both the categories are presented in Table 3. The optimization under wheat-mustard-based farming system resulted in an increase in the farm family's net income by 43 per cent in category I and 25 per cent in category II. The net income from optimal farming systems with water restriction was also higher by 41-42 per cent and 18-21 per cent, respectively in categories I and II as compared to that in the existing plans. The highest increase in farm income (60 per cent) was in the optimal farming system with a goat unit on small farms. The cost of goat-rearing under the semi-intensive system was quite low as the small farmers had access to grazing

Table 2. Optimum combinations of enterprises under potato-based farming system, per farm

Particulars	Category I					Category II			
		Optimum					Optimum		
	Existing	I	II	III	IV	Existing	I	II	III
Crop enterprises (acres)									
Potato	2.10(40.15)	1.94(29.31)	1.94(31.68)	1.94(32.83)	1.94(29.31)	17.10(67.75)	17.50(60.87)	17.50(61.86)	17.50(64.79)
Wheat	0.90(17.21)	0.80(12.08)	0.80(13.16)	0.80(13.54)	0.80(12.08)	1.08(4.28)	1.09(3.79)	0.80(2.83)	0.80(2.96)
Mustard irrigated	-	-	-	-	-	1.00(3.96)	1.00(3.48)	1.29(4.56)	1.29(4.78)
Mustard un-irrigated	-	0.17(2.57)	0.17(2.79)	0.17(2.88)	0.17(2.57)	0.41(1.63)	0.76(2.64)	0.76(2.69)	0.76(2.81)
Bajra	0.80(15.30)	1.00(15.11)	1.00(16.34)	1.00(16.92)	1.00(15.11)	1.12(4.44)	3.00(10.43)	3.00(10.69)	3.00(11.11)
Cucurbits	0.60(11.47)	0.50(7.55)	0.005(.001)	-	0.50(7.55)	0.60(2.38)	-	0.41(1.45)	-
Chillies	-	0.50(7.55)	0.50(8.17)	0.29(4.91)	0.50(7.55)	1.00(3.96)	2.00(6.96)	2.00(7.07)	1.26(4.66)
Brinjal	-	-	-	-	-	0.47(1.86)	1.00(3.48)	-	-
Sunflower	-	-	-	-	-	0.53(2.10)	-	0.13(0.46)	-
Fodder sorghum	0.74(14.15)	1.52(22.96)	1.52(24.83)	1.52(25.72)	1.52(22.96)	1.73(6.85)	2.09(7.27)	2.09(7.39)	2.09(7.74)
Fodder *berseem*	0.09(1.72)	0.19(2.87)	0.19(3.02)	0.19(3.20)	0.19(2.87)	0.20(0.79)	0.31(1.08)	0.31(1.09)	0.31(1.15)
Total cropped area	5.23(100)	6.62(100)	6.125(100)	5.91(100)	6.62(100)	25.24(100)	28.75(100)	28.29(100)	27.01(100)
Cropping intensity (%)	168.71	213.55	197.58	190.65	213.55	122.17	139.16	136.93	130.74
Livestock enterprises									
Buffalo	1.60	4.00	4.00	4.00	4.00	2.76	5.00	5.00	5.00
Local cow	-	-	-	-	-	0.23	-	-	-
Goat	-	-	-	-	10.00	-	-	-	-
Draft animal	0.40	-	-	-	-	0.23	-	-	-
Returns to fixed farm resources (Rs/annum)	49918	62959‘	59556	56923	68146	295098	320391	314984	303488

Note: Figures within the parentheses indicate percentages to total cropped area

Table 3. Levels of income and employment in optimal farming systems

Particulars	Wheat-mustard-based farming systems		Potato-based farming systems	
	Category I	Category II	Category I	Category II
Income, Rs				
Existing Plan	38693	89785	49918	295098
Optimum Plan I	55429	112199	62959	320391
	(43.25)	(24.96)	(26.12)	(8.57)
Optimum Plan II	54985	108270	59556	314984
	(42.10)	(20.58)	(19.31)	(6.74)
Optimum Plan III	54541	106423	56923	303488
	(40.95)	(18.53)	(14.03)	(2.84)
Optimum Plan IV	62015	-	68146	-
	(60.27)		(36.52)	
Family labour availability, man-days	822	951	1146	828
Employment generated, man-days				
Existing Plan	298	487	326	1513
Optimum Plan I	528	631	518	1822
	(77.18)	(29.57)	(58.90)	(20.42)
Optimum Plan II	528	616	487	1689
	(77.18)	(26.49)	(49.38)	(11.63)
Optimum Plan III	527	603	473	1612
	(76.85)	(23.82)	(45.09)	(6.54)
Optimum Plan IV	823	-	753	-
	(176.17)		(130.98)	

Note: Figures within the parentheses show the per cent increase in optimum over the existing

resources at no cost from fallow and common lands. The employment generated also increased in the optimal farming system by 77 to 176 per cent on the small farm and by 24 to 30 per cent on the large farm. In the optimal potato-based farming system, the farm income in category I (small farms) increased by 14 to 36 per cent under different plans. Increase in the farm income as a result of optimization on larger farms in category II was 3 to 9 per cent only. The smaller change in income on large farms indicated that these farmers were operating closer to the optimal situation and adjusting their activity-mix to the problem of water scarcity and availability of other resources. Similarly, the employment generated in optimal farming system increased by 45 to 131 per cent on small farms and 6 to 20 per cent in category II.

Table 4. Additional income and capital requirement in optimal farming systems

(in Rs)

Farming systems	Additional working capital	Additional fixed capital	Total additional capital	Additional labor used (man-days)	Additional net returns	Incremental capital-net income ratio	Additional capital requirement for one man-year employment*
Wheat-mustard-based farming system							
Category I							
Optimal Plan I	9108(33.23)	18300(66.77)	27408(100)	230	16736	1.64	35750
Optimal Plan II	9468(34.10)	18360(65.90)	27768(100)	230	16292	1.70	36219
Optimal Plan III	9826(34.94)	18300(65.06)	28126(100)	229	15848	1.77	36846
Optimal Plan IV	12312(29.59)	29300(70.41)	41612(100)	525	23322	1.78	23778
Category II							
Optimal Plan I	8013(34.22)	15400(65.78)	23413(100)	143	22414	1.04	49118
Optimal Plan II	8055(34.34)	15400(65.66)	23455(100)	129	19971	1.17	54546
Optimal Plan III	7968(34.10)	15400(65.90)	23368(100)	117	16638	1.40	59918
Potato-based farming system							
Category I							
Optimal Plan I	7895(24.75)	24000(75.25)	31895(100)	192	13041	2.44	49836
Optimal Plan II	7771(24.46)	24000(75.54)	31771(100)	161	9638	3.29	59200
Optimal Plan III	7652(24.18)	24000(75.82)	31652(100)	147	7005	4.52	64596
Optimal Plan IV	12215(25.87)	35000(74.13)	47215(100)	427	18228	2.59	33172
Category II							
Optimal Plan I	43237(65.87)	22400(34.13)	65637(100)	309	25293	2.59	63725
Optimal Plan II	36944(62.25)	22400(37.75)	59344(100)	176	19886	2.98	101154
Optimal Plan III	35874(61.56)	22400(38.44)	58274(100)	99	8390	6.95	176588

*time criterion i.e. 300 days

Note: Figures within the parentheses show the percentages

Additional Capital Requirement

The total additional capital requirement in both the categories was much higher under the potato-based than the wheat-mustard-based farming system. Wherever a higher number of livestock formed the component of farming system, the level of additional capital requirement was also higher (Table 4). The maximum additional capital requirement in the potato-based farming system was mainly due to more capital and labour-intensive nature of crops and entry of maximum number of additional buffaloes.

Conclusions and Implications

The optimization of resource-use under both the farming systems has indicated scope for readjustment in the existing enterprise pattern for maximizing farm returns. The increase in net returns due to optimum allocation of resources has been higher on small than large farms. Among the two farming systems, the increase in net returns due to optimization has been higher in the wheat-mustard-based farming system. In the optimum farm plans with reduced supply of irrigation water (by 10 % and 20 %), the farm returns have reduced marginally; however, the returns are still much higher than those in the existing plan. Therefore, optimization of resource-use and selecting crops that require less water for irrigation could be one of the strategies to overcome the problem of water scarcity. The livestock-rearing, especially buffalo-keeping has been highly profitable even under the water-scarce farming situations. Goat-rearing is another activity for increasing the income of small farmers.

In view of the alarming rate of decline in groundwater, the existing cropping pattern might have to be adjusted in favour of low water-requiring crops such as mustard, pigeon pea, barley, green gram and fodder crops like sorghum for increased number of buffaloes. However, this may be possible only through a technological breakthrough by increasing disease-resistance and productivity of these crops and continuous policy interventions for price support. Besides, increased efforts for harvesting and conservation of rainwater, and recharging of groundwater through proper watershed management are urgently needed. A proper maintenance of the village ponds might also play a crucial role in water conservation and recharging of groundwater. Instead of distributing common village lands to members of weaker sections, these lands to certain extent may be developed for water harvesting and conservation as ponds. This would eventually benefit all the sections of the rural society through improving the availability of water and consequently grazing resources. The role of livestock in water-scarce situations has been identified to be even more crucial for sustaining the households' income.

Mustard crop in wheat-mustard-based farming system has also provided an opportunity for additional income generation through bee-keeping. However, a very few farmers have successfully tried it. In fact, most of the farmers lack skills of bee-keeping. Through research and development, potato could also be utilized for starch making on a large scale, which could result in higher and more stable market prices for potato and consequently, its sustainable production. For all these development initiatives, peoples' participation is essential.

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