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Research Article

GROUND WATER RESOURCE SUSTAINABILITY IN AGRICULTURE: A MULTIPLE CRITERIA DECISION ANALYSIS (MCDA) APPROACH

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Abstract: Water is one of the scarcest resources due to increasing population while agricultural growth depends upon the availability water resource potential in India that includes both the surface and ground water potential. Objective of study was to find out major decision criteria practiced by the farmers to use the ground water and develop the optimum plan by using ground water through tubewell irrigation water for 54 randomly selected farmers from Nainital district of Uttarakhand. Likert scale technique and t-statistics was used to find out the most relevant decision-criteria practiced by the farmers while linear programming was used to obtain optimum plans under various decision criteria. Maximization of total gross margin, minimization of risk, minimization of total labor use and minimization of total working capital emerged as main decisions criteria on which farmers took decision for using tubewell irrigation water in the study area. Total gross margin was increased by 3.3% while risk value, labour use and working capital were decreased with 6.01%, 30.23% and 32.30% in the optimum plan over existing plan.

Keywords: *Likert scale, Multi criteria decision, Linear programming, Decision criteria, Irrigation water*

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Introduction

Water is a scarce resource and every drop needs to be used efficiently. About 85% of available water is used by agriculture, 4.5% by domestic purpose, and 2.7% by industries, 1.8% for generation of energy and remaining 8% by other sectors [1]. The economical use of water is one of the most important issues in agriculture. The adequate and timely availability of water is the most crucial one among the all basic inputs of agricultural production. The non-availability of water becomes a limiting condition for the fruitful use of other inputs like improved seeds, fertilizers, farm labour, power *etc.* because water becomes a catalytic agent for enhancing agricultural input. The lack of water creates a lag in adoption of chemical fertilizers and high yielding varieties of crops. The policy instruments have been designed on the assumption that agricultural producers behave rationally and seek profit maximization only. Hence, they use water as an input at a level where a marginal return equals marginal cost. However, a number of studies refute the hypothesis that farmers seek to maximize only profit but seek to optimize a broader set of objectives such as maximization of profit, minimization of risk, minimization of total labour used and the minimization of working capital *etc.* by using different inputs in agricultural production [2-6]. Many researchers have tried to integrate concepts of behavior and decision analysis in economic valuation. A subsistence farmer may be interested in maximizing cash income, securing food supplies for the family, increasing leisure, minimizing risk, *etc* while in commercial farmers may want to maximize gross margin, minimize his indebtedness, acquire more land, minimize costs and enhance social standing *etc.* Traditional researcher assumed that constraints have defined set which are rigid and cannot be violated under any circumstances. Therefore, research is needed in order to investigate the farmer's decision-making process in using the available water input in the context of multi-criteria analysis framework. This study was conducted in Uttarakhand state of India. The water is most scarce resource in Uttarakhand agriculture after land. The non-availability of irrigation water becomes a limiting factor in adaptation of improved production practices such as seeds, fertilizers, farm labour and machinery *etc*. However, water will remain being the scarce resource in future owing to its multiple uses and increased demand in crop production. The question, how to make judicious use of water will be crucial for the growth of agriculture? To have sustainable livelihood security and improved standards of living, the farm families need to generate additional income from the available farm resources. The objective of the study was to estimate major decision criteria for using irrigation water resources and optimal plan on the basis of these decision criteria in farming.

Material and Methods

The present study was conducted in Haldwani block of Nanital district of Uttarakhand state. The district of Nainital comprises of eight development blocks and Haldwani block was selected purposively on the basis of maximum area irrigated by state tube-well. Two state tube-wells were selected randomly. The length of the selected channels of state tube well were divided into three equal parts namely, head, middle and tail thereafter two outlets was randomly selected from each part thus making a total of 6 outlets. Nine farmers were selected randomly from each outlet thus making a sample size of 54 farmers. The primary data was collected from secondary data by using survey schedule method and secondary data was collected from government records and published sources.

Estimation of decision criteria practiced by farmers

t-statistics was used to find out the most relevant decision-criteria practiced by the farmers in farming. Farmers were interviewed and responses of the farmers were obtained on a 5-point Likert scale (strongly agree-5, agree-4, undecided-3, disagree-2, strongly disagree-1). The average of the farmers' responses to particular decision criterion was calculated. The decision criteria with average score significantly higher than 3 was considered as most relevant decision criterion practiced by farmers in farming.

The significance difference of estimated average score from undecided (score-3) was tested using t-test of the following forms:

$$t_{cal} = \frac{\overline{X}_i - 3}{\sqrt{\frac{s_i^2}{n}}}$$

Where,
t_{cal} = t-calculated
$\overline{X}_i$ = sample mean of i^{th} decision criterion
s_i^2 = sample variance of the i^{th} decision criterion
n = represents sample size

Optimum plan on the basis of decision criteria followed by farmers
Linear programming was used to obtain optimum plans for taking irrigation water as an input under various decision criteria followed by selected farmers in the study area.

Maximization of Total Gross Margin (TGM) = $\sum_{j=1}^{n} C_j X_j$

Subject to

$$\sum_{j=1}^{n} a_{ij} X_j \le B_i$$

$$X_j \ge 0$$

TGM= total gross margin
Cj = average gross margin per unit of the j^{th} crop activity (calculated from time series data of crop gross margins from 2000-2001 to 2007-2008 at constant price of 2000).
X_j= level of the j^{th} activity
a_{ij}= the amount of the i^{th} resources required by per unit of the j^{th} crop activity
b_i = i^{th} resource available on the farm for use in the production of crops
i =1, 2................m indicating the number of rows (constraints)
j =1, 2................n indicating number of columns (crops)

Minimization of risk (V_{min}TGM) $= \sum_{i=1}^{n} V_j X_j$

$$\sum_{j=1}^{n} C_j X_j \ge \text{TGMmin}$$

Where,
V_j = variance of gross margin per unit of crop activity during sevenyears period (from 2000-2001 to 2007-2008)
X_j = level of the j^{th} activity
C_j = average gross margin per unit of the j^{th} crop activity
TGM_{min}= minimum total gross margin in a particular year during sevenyears period
The variance of crop gross margin was used to assess risk. The risk is computed as following form:

Risk = $\vec{X}^t$. (COV) $\vec{X}$
$\vec{X}^t$ = transposed of crop decision vector (row vector)
(COV)= variance-covariance matrix of the crop gross margin
$\vec{X}$ = crops decision vector (column vector)

Minimization on of total labour (L) $= \sum_{i=1}^{n} L_i X_i$

Subject to

$$\sum_{j=1}^{n} a_{ij} X_j \le B_i$$

$$X_j \ge 0$$

Where;
L_i = the labour requirements of the per unit crop activity
X_i = level of the j^{th} crop activity

Minimization of working capital (WC) $= \sum_{i=1}^{n} k_i X_i$

Subject to

$$\sum_{j=1}^{n} a_{ij} X_j \le B_i$$

$$X_j \ge 0$$

Where;
k_i = the working capital requirements of the per unit crop activity
X_i = level of the j^{th} crop activity

Data for technological matrix
Data for technological matrix refer to input-output coefficient of different activities. Different crops grown by the farmers in the study area were taken as the real activities. The crops grown were paddy, wheat, sugarcane (planted and ratoon), pea, maize, tomato, okra, soybean, gram and mustard *etc*. The input coefficients are the required amount of different inputs per unit activity and the out-put coefficient is the gross margin per unit of the same activity. For calculating the gross margin per unit activity for different activities only variable costs were taken into account.

Land constraints
The availability of land was taken as a constraint. There was no possibility of increasing the area of farm by way of purchase or lease in a short period. Therefore, leasing activity of land has not been included in the model. Land was classified into *kharif* land and *rabi* land based on season. The area allocated to sugarcane was counted in both the seasons and assumed that the whole land was irrigated by field channels.

Human labour constraint
The availability of family labour hours on the farms during different months was estimated according to the number of family members engaged in farming. The maximum number of labouers hired by the farmer in any month was taken as the maximum limit in hiring labouer in a month.

Irrigation water constraint
Monthly availability of irrigation water for irrigation was estimated based on hours of canal run, kolaba's size and kolaba's discharge rate while in case of state tube well it was calculated based on discharge rate of state tube well and number of hours allotted to farmer for irrigation purpose.

Working capital constraint
Working capital available per unit activity was based on the farmer's credit limit set by the cooperative society in the form of cash, kind and farmer's own resources.

Result and Discussions
A list of probable decision criteria, which was presented before the 54 farmers to rank the decision criteria followed by them for using water input farming, is shown in [Table-1]. They were asked to rank each decision criterion on the basis of five points Likert Scale (strongly agree-5, agree-4, undecided-3, disagree-2, strongly disagree-1) from strongly agree to strongly disagree.

The average score of the responses of farmers to each decision criterion
Mean and standard deviation of each decision criterion of respondent farmers according their perception of each criterion is presented in [Table-2]. The average score of each decision criteria and frequency distribution of farmers according to their perception showed that out of 17, only 4 decision criteria were found agreed categorized and 13 were disagree categorized. The decisions criteria which were statistically found strongly agreed upon with corresponding average scores were, maximization of total gross margin (4.768), minimization of risk (4.324), minimization of total labour used (4.685) and minimization of working capital (4.129). The average score of the farmers' responses to these decision criteria were found to be statistically greater than three.

Table-1 *Frequency distribution of sample farmers' response to each decision criterion*

Scale Decision	Strongly agree	Agree	Undecided	Disagree	Strongly disagree	Total
Maximization of total gross margin (TGM)	45(83.33)	6(11.11)	3(5.55)	0(0)	0(0)	54
Minimization of risk	34(62.96)	10(18.50)	6(11.11)	4(7.40)	0(0)	54
Minimization of total labor use (TL)	39(72.22)	13(24.07)	2(3.70)	0(0)	0(0)	54
Maximization of leisure time of farmer	0(0)	1(1.85)	6(11.11)	12 (22.22)	35 (64.81)	54
Maximization of total bullock power use	3(5.55)	6(11.11)	5(9.25)	28 (58.85)	12 (22.22)	54
Minimization of total tractor hour use	2(3.70)	8(14.81)	20(37.03)	12(22.22)	12 (22.22)	54
Maximization of total FYM use	5(9.25)	6(11.11)	23(42.59)	19 (35.18)	1(1.85)	54
Minimization of total inorganic fertilizer use	6(11.11)	8(14.81)	28(58.85)	6(11.11)	6(11.11)	54
Maximization of total biofertilizer use	0(0)	8(14.81)	15(27.77)	19 (35.18)	12(22.22)	54
Maximization of total micronutrient use	0(0)	3(5.55)	12(22.22)	17 (31.48)	22(22.22)	54
Minimization of total insecticide use	2(3.70)	6(11.11)	14(25.92)	12 (22.22)	20 (37.03)	54
Minimization of total pesticide use	3(5.55)	7(12.96)	17(31.48)	6 (11.11)	21 (38.88)	54
Minimization of total herbicide use	7(12.96)	12(22.22)	29(53.70)	4(7.40)	2(3.70)	54
Maximization of manual intercultural operation	1(1.85)	9(16.66)	20(37.04)	19(35.18)	5(9.25)	54
Minimization of irrigation water use	2(3.70)	10(18.51)	5(9.25)	2(3.70)	35(64.81)	54
Minimization of transportation cost from farm to home	3(5.55)	3(5.55)	6(11.11)	14(25.92)	28(51.85)	54
Minimization of total working capital	28(51.85)	12(22.22)	8(14.81)	6(11.11)	0(0)	54

Table-2 *Response of sample farmers towards different decision criteria*

SN	Decision criteria	Mean	Standard deviation
1	Maximization of total gross margin (TGM)	4.768	0.54
2	Minimization of risk	4.324	1.002
3	Minimization of total labor use	4.685	0.54
4	Maximization of leisure time of farmer	1.509	0.767
5	Maximization of total bullock power use	2.268	1.115
6	Minimization of total tractor hour use	2.527	1.097
7	Maximization of total FYM use	2.925	0.954
8	Minimization of total inorganic fertilizer use	3	1.059
9	Maximization of total biofertilizer use	2.379	0.983
10	Maximization of total micronutrient use	1.962	0.946
11	Minimization of total insecticide use	2.398	1.282
12	Minimization of total pesticide use	2.373	1.279
13	Minimization of total herbicide use	3.361	0.921
14	Maximization of manual intercultural operation	2.675	0.965
15	Minimization of total irrigation water use	2.435	0.845
16	Minimization of total transportation cost from farm to home	2.074	0.861
17	Minimization of total working capital	4.129	1.068

Table-3 Optimum value for different decision criteria in tubewell irrigated system in the study area

Irrigation system	Objective	Objective Function Value		Water used (m3)	GCA	NCA	CI (%)
State tube well	Maximization of TGM (Rs.)	E	29375.3	4735	2.03	1.25	162.4
		O	30347.5	6122	1.93	1.25	154.58
		Δ (%)	3.3	29.3	-4.9	0	-4.9
	Minimization of risk (Rs.)	E	1239.88	4735	2.03	1.25	162.4
		O	1165.34	6225	1.89	1.25	151.06
		Δ (%)	-6.01	31.47	-7.03	0	-7.03
	Minimization of labour use (hrs.)	E	280.82	4735	2.03	1.25	162.4
		O	195.91	1929	2.27	1.25	181.03
		Δ (%)	-30.23	-59.27	11.45	0	11.45
	Minimization of working capital (Rs.)	E	14879.1	4735	2.03	1.25	162.4
		O	10072.7	1846	2.23	1.25	178.38
		Δ (%)	-32.3	-61.02	9.83	0	9.83

Results were further supported by percentage of farmers which take decision of using inputs. About 94.44%, 79.62%, 96.29% and 73.14% farmers who responded that either strongly agree or agree to these decision criteria on the basis of take decision of input used in farming.

Optimal plan for farmers by taking irrigation water used

Tubewells were main sources of irrigation in the study area and optimum plan was found for tube well irrigated area. The farmers had different objective on the basis of decision taken for using water input in farm business. In state tube well irrigation system, the value of total gross margin was increased by 3.3% in optimum plan of maximization of TGM while the value of risk, labourer used and working capital used was decreased by 6.01%, 30.23% and 32.30% in the objective of minimization of variance of TGM, minimization of labour used and minimization of working capital respectively.

Optimum plan for state tube well irrigation system

The optimum crop plans for the entire state tube well irrigation system is given in [Table-4]. In this region of the irrigation system paddy, wheat, sugarcane and tomato occupied land area viz, 0.38 ha, 0.23 ha, 0.47 ha and 0.20 hectare, respectively, which was changed in the optimum crop plan for maximization of TGM as 0.42 ha, 0.26 ha, 0.57 ha, and 0.22 hectare, respectively. The total gross margin increased by 3.3 percent in maximization of TGM while risk decreased by 6.01 percent in minimization of variance (TGM), labour decreased by 30.23 percent in minimization of labour use and working capital by 32.3 percent in minimization of working capital, respectively. The optimum crop plan for maximization of TGM showed decrease in the area of soybean (41.46 percent), maize (45.94 percent), okra (19.04 percent), pea (15.15 percent), mustard (50 percent), gram (100 percent) and rajma (28.57 percent) from existing value. In the objective function for minimization of variance (TGM) there was decline in the area of soybean (100

Table-4 *Optimum crop plans for different decisions criteria in tubewell irrigated system in the study area*

Irrigation system	Objective	Crops	Paddy	Soybean	Maize	Okra	Sugarcane	Wheat	Tomato	Pea	Rajma	Gram	Mustard
	Existing	E (ha)	0.33	0.18	0.18	0.16	0.46	0.27	0.29	0.11	0.09	0.01	0.09
State tube well	Existing	E (ha)	0.38	0.13	0.12	0.14	0.47	0.23	0.2	0.11	0.07	0.05	0.11
	TGM (Rs.)	O (ha)	0.42	0.08	0.06	0.11	0.57	0.26	0.22	0.09	0.05	0	0.05
		%Δ	10.43	-41.46	-45.94	-19.04	21.27	14.49	6.45	-15.15	-28.57	-100	-50
	Risk (Rs.)	O (ha)	0.41	0	0.19	0.03	0.61	0.31	0.21	0	0	0	0.1
		%Δ	6.95	-100	56.75	-73.8	30.49	37.68	4.83	-100	-100	-100	-5.88
	Laboure (hrs.)	O (ha)	0.22	0.26	0.28	0.24	0.23	0.13	0.23	0.17	0.18	0.14	0.15
		%Δ	-40.86	92.68	129.72	73.8	-49.64	-42.02	14.51	54.54	161.9	162.5	35.29
	WC (Rs.)	O (ha)	0.21	0.21	0.25	0.3	0.27	0.13	0.21	0.15	0.22	0.13	0.13
		%Δ	-43.47	53.65	102.7	119.04	-42.55	-42.02	1.61	42.42	219.04	143.75	14.7

percent), okra (73.8 percent), and mustard (5.8 percent) while gram, rajma and pea did not appear in the optimum plan. Paddy (40.86 percent), wheat (42.02 percent), and sugarcane (59.64 percent) showed decrease in minimization of labour use while in minimization of working capital saw decline in the area under paddy (43.47 percent), wheat (42.02 percent) and sugar cane (42.55 percent) while rest of the crops showed an increase.

Summary and Conclusion

The farmers took decision with respect to water use not only maximization of total gross margin (TGM) but based on several other factors, such as minimization of risk, minimization of labour and minimization of working capital. For the successful implement of any agricultural policy with respect to input use, it would be more appropriate if other important decision criteria are taken into account. The difference in input use observed in any agricultural systems should be explained in terms of weights assigned to each decision criteria according to which farmers' takes decision in farming. The weight attached to each decision criteria varies from farmer to farmer due to psychological, social and economic factor of farmers within homogeneous agricultural area.

Application of research: The farmers took decision for using the input with respect to number of criteria. For the successful implement of any agricultural policy with respect to input use, it would be more appropriate if other important decision criteria are taken into account.

Research Category: Decision Science and multi-objective programming

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Cultivar / Variety / Breed name: Nil

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References

[1] Central Water Commission (2000) *Country, Report of the Standing Sub-Committee (BP Directorate) August,* 2000.

[2] Gassion R. (1973) *Journal of Agricultural Economics*, 24(3), 521-537.

[3] Harper W.H. and Eastman, C. (1980) *American Journal of Agricultural Economics*, 62(4), 742-747.

[4] Willock J., Deary I.J., Jones G.E., Gibson G.J., Mcgregor M.J., Sutherland A., Dent J.B., Mogan O. and Andgrieve R. (1999) *Journal of Agricultural Economics*, 50(2), 286-303.

[5] Rehman P. and Romero C. (1993) *Agricultural Systems*, 41(3), 239-255.

[6] Kotchen M., Reiling S. (2000) *Ecological Economics*, 32, 93-107.

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