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Application of Operation Research Techniques in Agro Practices with Respect to Multiple Decision Variables

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Abstract

In current environmental scenario, water scarcity is a crucial problem, as need of water increasing rapidly and its availability is not up to mark. Therefore, it becomes necessary to develop scientific methods to utilize the water at its optimum level. The major aim of this study was to device a distinct linear programming model, keeping in mind a group of certain technical variables that may affect the revenue and profit of an agricultural irrigation plan. This model shows an objective function which increases the total revenue and also decides the frequency of water availability. It is presumed that production function in response to water usage is there and freely available for certain crops and explains the water consumption and crop production relationship. The LPP model is designed heritably to ensure that the logical usage of the total accessible water resources can be considered for irrigation plan in certain specific linear equations which were formulated and used in the irrigation plan on the water consumption and crop production function, total cultivated land and the various types of cost involved in it.

Key Words

Operation Research, Linear Programming, Optimisation Problem, Multiple Agro Decisions

(1) Introduction

In order to plan out water availability and supply of water in any irrigation plan, it is important to decide that total accessible water and total requirement of the water. To determine such things it is also important to take following things into consideration. Such as, need of water distribution in every month as well as in every season, production of crop, selection of crop, investigation of models and timetable for water distribution during specific period of growth. In order to make optimum decision, a cultivator must select from various available production options, the most effective use of factors of production needs to be determined and it is also important to indentify that which one is the most important factor that help to satisfy objective function. In case where the decision is linked to the distribution of limited resources, the planter is responsible to decide up the most effective technique which will help him to take the accurate decision. In order to crack this difficulty the linear programming model is the most appropriate solution

The Linear programming in form of mathematical programming quantify the best possible way of mixing limited resources to realize the objective of the activity or function to be performed. Typically LP analyze the cases where the available inputs needs to be mixed in order to optimize the revenue or cost. The profit maximization in the area where the water is limited or scarce in nature requires effective irrigation facility. Such practice of irrigation with deficit water is known as partial irrigation.

This sentence can be backed by some researches in the field of economics; these researchers believe that when the water availability is in scarce, the consideration about crop and area under irrigation selection must be based on profitability of the crop. As per the effect generated due to the requirement of the water are responded by availability of the water during crop season.

Some good researchers have said that in the case of irrigation in area where there is scarcity of the water or the availability is in the limited sources, very stringent planning to combat with the problem with such limited water is required. Planning and management of the available water must be done properly to solve such problem. Estimation of the irrigation requirement is needed for different crops and soils must me consider to get right cropping pattern. The planning of such irrigation project is regarded as most favorable in nature. As per economical values, if the solution to increase the difference between income and expenses of production to certain limitation poised in the production system. Studying the relation between income and expenses, such problem can be logically solved with the help of mathematical or LP model.

In this part of study, it is understood that the functions of production are available and they signify water and production association precisely. Such functions are included to a separated LP model that considers a group of many factors which has influence on the profitability of the irrigational project. It is important to balance the model to show the logical use of water in irrigational projects.

(2) Model Development

The objective function is decided as the total revenue increase or it is also known as revenue maximization as a result of production of certain crops with subject to certain constraints like total available water, and available area for farming. The gross revenue by area as a unit is decided as in direct proportion to the production, where as the expenses are considered as non variable part. The variable part is depends on the total irrigation take place in the season.

The gross revenue is shown as:

$$IB = \sum p_i * x_i * y_i(W) \quad \text{……………..} (1)$$

Where,

IB = gross revenue earned by n crops in an X area;

p_i = selling prices of the crop product i,

y_i (W) = crop yield I in function of the irrigation depth, in kg.ha*l;

x_i = cropped and irrigated area with crop i, in ha; and

i = an integer pertaining to the crop (1, 2... n).

Taking water as the distinct factor which is variable in nature, to the methodological union the production expenses are shown:

$$\mathbf{C}\, p_i = C_i - C_w * w_i \ \ldots (2)$$

Where,

C p = production expenses of the farm;

C_w = Cost of water irrigation

W_i = depth of irrigation (seasonal), used to the crop i, in mm; and

C_i = cost of producing crop i, not indirectly linked to the total irrigation.

The objective function of the economical unity was formulated as shown below:

$$Z = \sum P\, y_i + \sum W_i - \sum \mathrm{C}\, p_i - \sum C_i * W_i \ \ldots\ldots\ldots. (3)$$

Where,

Z = net income of the farm resulting from n crops with irrigation depth Wi,

The restraining factor to which the objective function is subjected to be generally written as shown below:

$$\sum W_i * \sum V_a \ \ldots\ldots\ldots(4)$$

$$\sum W_{ij} * A_j + \sum Va * a_{ij} \ldots\ldots\ldots\ldots (5)$$

Where,

If two reference points are considered:

(Y_{io} , W_{io}) signifies the maximum productivity and the equivalent irrigation depth and (Y_{is} , W_{is}) symbolize the minimum productivity and the equivalent irrigation depth, a decline in the irrigation depth of the crop i from W_{i0} to W_{i1} (DW_{i1}) implies a productivity decrease from Y_{io} to Y_{i1} (DY_{i1}); a drop from W_{i1} to W_{i2} ((DW_{i2}) results in Y_{j1} to Y_{j2} (Y|2) and this way sequentially. Normally, a decline in the irrigation depth from Wj k-1 to Wjk (DWjk) results in a productivity drop from Yj k-1 to Y_{ik} (DYjk). The area between Y_{jo} and Y_ss is the coherent zone for resource distribution.

It begins from a point where the mean product/unit of resource is highest and ends at the point where the highest product is attained. The irrigation depth most be selected somewhere between s and zero, where marginal water productivity is the same to its cost.

The model symbolized by the equations (3), (4) and (5) will be customized here considering the linear answer functions by parts to n crops. Bearing in mind that all crops are irrigated with a depth to attain maximum productivity (WjO) to an X area, the following gross revenue function can be obtained:

$$IBo = \sum PYi * n + \sum Xi * W0 \;\ldots\ldots\ldots\ldots(6)$$

Where,

IB_0 is the gross revenue achieved with n irrigated crops with depth W_0, in RS. The fall of the irrigation depth from W_w to Wjl (DWjl) implies in the decline of the gross returns of the crop i from IBjO to IBjl (DIBjl). In the similar way, a depth decline from Wjl to Wj2 (DWj2) results in the decline of the gross revenue from IBjl to ***IB{2*** (DIBj2), and so on. To any i crop, the sum diminution of the gross returns until a **k** point will be: Considering n crops where each one gives **D I B j k ,** the following can be observed:

$$\sum \Delta IB = \Delta IB2 - \Delta IB1 \qquad \ldots(7)$$

Assuming that there is no difference in the sum area accessible for irrigated cropping when the irrigation depth is diverse and only the yield of the crop can differ for n cultures the equation can be strained**.** For an irrigation depth **W j O** and area **X**.0, the crop production cost **i ,** related to the irrigation depth. The fall of the irrigation depth from WjO to Wjl (DWjl) fetches a cost decline from CPjO to CPjl (DCPjl), and so on. The cost cutback comes only from the water outlay.

The net profits attained for n crops in an X area, irrigated with the water depth Wk. The plan of the economical unity is to capitalize on the net income function (Z). This maximization was set up following the limitations below. (a) the water quantity consumed in the irrigation at k level ought to not exceed the maximum volume available:

$$\sum_{i=1}^{n} x_{io}\, w_{io} - \sum_{i=1}^{n}\sum_{k=1}^{s} x_{ik}\, \Delta\, w_{ik} \leq Va \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

$$\sum_{i=1}^{n} x_{io}\, w_{io} - \sum_{i=1}^{n}\sum_{k=1}^{s} x_{ik}\, \Delta\, w_{ik} \leq Vm \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

Where,

w_{jk} = total water depth applied during the growing season i, at irrigation level **k,** in nun;

w_{jk} = monthly water depth applied to the culture **i,** at irrigation level **k,** in mm;

Va = annual water volume available, in mm.ha; and Vm = monthly water volume available, in mm.ha.

(b) Cropped area restriction for crop **i:**

$X_{i0} < ou > G_i$ **... (10)**

Where Gi is the restricted cropped area (ha) for crop **i.**

(c) Total planted area restricted to each month:

$$\sum_{i=1}^{n} x_{io} \leq Sm\ form = 1,2, \dots .(11)$$

Where *Sm* is the total area available (ha) for the cropping in the month m.

(d) the irrigated area with w_{ik} depth must not exceed the irrigated area with the depth for the maximum production:

$$X_{ik}\text{-}X_{i0}<0, for = l, 2 \dots n \dots\dots\dots (12)$$

(e) non-negativity:

$$X_{io} >0 \ and \ X_{ik}>0 \dots\dots\dots\dots (13)$$

(3) Application of the Model

The proposed model can be used to any irrigation plan, preferably in the place where the problem of water scarcity is prevailing or where there is very high demand for such irrigation plans. The important co-efficient of the proposed model is taken from the fact that it is based on the data collected from the supervision report of particular period of agriculture activity.

The major goal is to get best possible system of crop irrigation with respect to total area available for agricultural exploration. This will help to increase the total revenue for the project. The limitation are demarcated in the plan are like total accessible water, land and market for the crops.

TABLE 1 reflects the most habitual crops of the Ahmedabad region considered in the analysis done in this study. Their answer functions to water, sawing season, production expenses excluding the water cost and the product price taken. Such crops represent an job of approximately 90% of the populated area of this project, whose blueprint of monthly occupation is shown on TABLE 1

Table No. 1
Characterizations of crops under study

Crops	Showing Season
Soya beans	July
Watermelon	February
Watermelon	July
Wheat	October
Pulses	July
Tomato	May
Onion	February
Banana	##
Corn	July
Corn	October
Sugarcane	##

= consider for next season

The project has 9820 hector irrigated designated to 1,724 settlers. Nowadays, the total area explored by the settlers with the proposed crops is of 7,241 hector. The residual area is set aside to other crops such as mango which have just been rooted.

The restrictions to the cropped area are the following:

(a) Soya beans planted in July: Minimum area = 714 ha; reason - internal utilization.

(b) Watermelon Planted in February maximum area = 2,854 ha; cause - market.

(c) Watermelon planted in October minimum area = 2,854 ha; rationale - market.

(d) yearly area of watermelon in the project: maximum area = 4,281 ha; cause - market.

(e) Pulses grown in July: maximum area = 2,141 ha; minimum area = 714 ha; cause food processing capacity.

(f) Tomato grown in May: maximum area = 4,281 ha; minimum area = 714 ha; cause food processing capacity and market.

(g) Onion grown in February maximum area = 357 ha; cause -farmers resistance to aspersion.

(h) Banana: maximum area = 2854 ha; minimum area = 714 ha; cause - food processing capacity.

The crop water necessities during the rising season were predicted based on the production functions. This monthly prerequisite was anticipated giving the total irrigation depth in context to maximum monthly evaporation for each crop.

(4) Results and Discussion

Table No. 2
Cropping Calendar

Months/ Crops	*Soya*	*Sugarcane*	*Watermelon*	*Corn*	*Onion*	*Wheat*	**Tomato**	*Pulse*	*Banana*
Jan.								X	
Feb.					X				
March					X				
April									
May	X						X		
June	X						X		
July	X		X				X		
Aug.			X				X	X	
Sept.			X					X	X
Oct.		X		X		X			X
Nov.		X		X	1 1	X			X
Dec.		X		X		X			X

(5) Optimal Solution of the Model

Taking the water as limitation and fulfilling the optimal farming areas necessities, the given model has resulted in the most favorable farm planning; the soya beans crop was only shown for sawing in the month of July with 714 hector of land, defined by the need of fulfilling the original usage, with the suggested irrigation of 510 mili meter. The watermelon was grown in the month of October and it has lowest i.e. 714 hector and highest 4281 hector are as limiting factor due to the market consumption, the model anticipate that only 714 hector of crop with a view to satisfy the lowest requirement, with 450 mili meter total water. The 714 hector of pepper crop is suggested in the model and it must receive total water of 440 mili meter.

With a view to grow tomato in the month of May, it was suggested that the land of 3.082 hector with the accessibility of water of 500 mili meter is needed. The onion needs the total water of 790 m.m. it was shown in the highest level. The banana will need 1843 hector of land with 2100 m.m. of water throughout the year. All the crops have to get total irrigational deficit, and the suggested level were those which resulted in the highest reveue.

(6) Marginal Cost Associated with the Non-basis Crop Activities

The plant that were not suggest, are known as non basis variable of the model. The model has marginal cost in form of such variables, which are known to lower the net revenue of the total cultivated land. Marginal cost of the non-basis plants are indicated, for the purpose of irrigation, except water deficit. For instance, the soya bean plant was not shown for the month of May, and in such issue, there is marginal cost related with this function. It means that in each land unit of plant sown in the month of May and irrigated devoid of deficit of 545 m.m of water will lead to drop of rs. 1598 in the total income.

The proper solution of given model shows that the farming of the below mention crops at the lesser land limits:

Soya beans grown in July (714), Pulses grown in July (714), Onion grown in February at the highest limit of 357 and the watermelon grown in the month of October (714). All the above mentioned land areas are in hector.

(7) Sensitivity Analysis of the Available Water Volume

The optimum cultivation pattern determined by the solution of the model resulted in a consumption of all available water. The monthly availability was not limiting. Since the annual volume is a scarce resource a shadow price value is associated, which corresponds to the expected reduction of the value of the object function in case this volume becomes more scarce in one unit. In this case, if the annual water availability is reduced by 1000 m^3, the net income is reduced marginally.

On the other hand, the net income can be increased by the same value if 1000 m are added. In this way the shadow price of water represents the maximum value which the user could be willing to pay in order to have one additional unit of volume.

The maximum and minimum volumes of water represent the limits of water availability for which the shadow price is valid and the optimum solution is not altered, they can, however, modify the cultivated areas. For example, the annual water availability is allowed to vary between 48,579,700 m^3 and 82,819,700 m^3 without change of the shadow price and the optimal solution. The lower limits of monthly availability are shown. For example, in May, volumes greater than 5.142.124 m^3 allow the solution to maintain the same optimum value and a shadow price of zero. It can also be noted that July, August, October and December present the greatest lower limits, showing that in these months the consumption was greater.

(8) Sensitivity Analysis of the Basic Variables Marginal Net Income

In common way, it is likely to have change in the total marginal income of fundamental activity, except the change of the most favorable level in the result. It is the limit recognized by the highest and lowest marginal revenues and the value identified in the given model, the permissible change gaps for the marginal revenue of the basis variable indentified in the most favorable solution of the problem, known as the real. It seems that the soya beans grown in the month of July and irrigated with the 510 mili meter water will remain at the base, with 714 hector, even its marginal income changes between considerably. If the value of the Rs. 945.89 per hector will remain on 714 hector since it is lesser limit of the given constraint. The water depth lesser that 530 m.m. may be suggested. Same analysis can be done for water melon too.

Onion should be grown on the area of 357 hector which is upper level limit and water depth of 790 m.m. for any value of the upper net marginal revenue of 6327 per hector. Its land area and water availability can be lesser only if the revenue would be lesser that this value.

In case of banana, the area of 1843 hector and the irrigational ability of 2100 m.m. is the most possible and favorable solution while the marginal revenue changes between considerably. Lesser revenue will lead to lesser area and irrigational water depth, and more values will lead to increase in this value to the upper level of limit.

(9) Analysis of the Annual Available Water Volume

In performing analysis of the total availability of water in the study it was seen that for values less than 1,78,50,000 cubic meter, the solution of the model was not feasible in nature, it shows that the model limitation are not fulfilled, especially those which restrict the lower harvested areas. For same or more volumes, the give result is feasible and it is basic solution of the model. For yearly volumes less than 8833893 cubic meter keeping the highest monthly volumes at 9861040 cubic meter, the model shows a total use of available resources in the best possible way. For the volumes higher than the shown value signifies excess and that is why a shadow price same as zero. It can be seen that the net revenue of the plan rises as a function of the rise in annual water availability. The available value depends on the monthly availability of the water. The shadow price is accepted when it is ranging between certain limits of net available inputs. The lowest price will take place when the project has the ability to provide amount of water between 88324703 and 88338983 cubic meter. The higher values will have zero shadow prices. So, this is how land use modeling in linear programming.

In a condition with more water availability, the plants of the lesser income per area of unit are irrigated in such manner that and rise in net income per additional unit of water may lower down. If this is the mean amount that the plan can provide, and with the objective of investing capital with a view to increase efficient use of water and availability also, the investment will be right decision if it achieve more per unit value in terms of income. When it will reach to the maximum value or equal value to its shadow price. The misuse of water signifies that the shadow price should be equal to the forgone net revenue per unit of water that remains unused.

At this association, its not likely that the user will utilize more water amount then what he actually needs. In the projects, if the water is limited input, the water prices would be different and such different prices will be accepted by the user. So, the users will not waste water more as he is supposed to pay high shadow price for the same.

(10) Consideration on the Model and its Use

As per the water demand curve of farmers' available based on the methodology based in certain hypothesis with the constraints. In the beginning, it was propounded that when the water accessibility is less, the irrigation plan user will use first that crop which has more income generation ability. As the water accessibility increases, the plants with the lower revenue generation ability will be sown. So, the available demand curve presumes that the water and other inputs in used effectively. However, the technological level in the users is different, so, with the same amount of water some users will generate more income than others. With the help of Geographical Information system LP can be very much effective in making irrigation related decisions.

Other restriction of the given model deals with the uncertainty in which the user is subjected to. The aim of the function taken in to account here, admits that the given model of income and expenses is not most favorable. Either the revenue or the costs are subject to change. So, it is not always possible to ensure a fixed level of income or the price of the product or resources. One way out of this problem will be to involve in the model of probability elements to take risk factors in the account. The major ways for these models can be generated in two groups, as per the treatment give to the origin of uncertainty. In the first group, only the sources of the uncertainty related to the income and expenses are listed. In this issue, the main uncertainty origin like prices, cost and marginal income etc are paired with the one risk part, expressed in the objective function.

In the other group, the ways that involves in the mathematical models the randomness of the technical values of the limiting factor and the amount of total available resources. This way is normally known as stochastic programming in LP. In any case, the model ling is very difficult and needs variety of time bound information, what are not available easily.

Labour related issues and problems are also considered for its influence in the case study. The effect of labour problems on shadow price is anticipated. The lower labour availability, because of problems in getting right number of people, the lower will the price farmer sill pay for water usage. This is because of the fact that because of low labour power, the total cultivated land can be reduces and as a result of this, the total revenue of the land imply in lesser availability of the inputs for water.

It is very much obvious that the price is being charged based on investment and cost of operations or certain sort of tariff charged to the farmer or the consumer of the service. The water rate subsidy is only justified when the rates are more than the shadow price. As it is monopoly of the government to provide services like irrigation, generally there is not logic or rationale given for the price charged.

(11) Conclusions

(a) Model was appropriate for the organization in optimal cropping outline and showing the water requirements.

(b) For 7,424 ha of area and 66,644,500 cubic meter of water accessible annual basis, the opportunity cost of these inputs were respectively, 1,115.20/ha e 281.60 / 1000 cubic meter.

(c) For the total per month water accessibility of 9,861,040 cubic meter, the total yearly water accessibility of 66,644,500 m became an successful restriction to the raise of the net returns of production system under research.

(d) Continuing the total per month water accessibility of 9,861,040 m^3, yearly volumes lesser than 88,338,983 cubic meter were used fully to reach the most favorable solution, and that upper volume man this limit, did not raise the net revenue.

(e) The optimization model anticipated net returns of 52.34 % more than the fixed cropping model.

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