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OPTIMIZATION MODEL FOR CROP DIVERSIFICATION IN INDIAN PUNJAB

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Abstract: The ideal utilize of soils is the premise of all types of economical land utilize, that is, farming area utilize that remaining parts profitable in the long haul. There are numerous advantages of an ideal utilization of soils, for example, a reduction of provincial destitution, watershed insurance, expanded biodiversity, and more supportable agrarian creation. Maintainable agrarian soil utilize requires making the land accessible for cultivating as gainful as could be expected under the circumstances while considering the ecological effect of the development procedure. Under regular conditions, soils present synthetic confinements for crop improvement. Diversified crop models are used to find out the suitable soil for the good production of the crop. As indicated by the prerequisites of products to be developed, it is regular to modify soil concoction qualities, changing the amount of supplements and acidity through fertilizing and liming, making profitable agribusiness conceivable however if farmer is going to select the soil according to the crop requirement then no need to add extra fertilizers which will reduce the production cost. The model proposed by author will help to select the optimal crop according to the soil components.

***Keywords*: Optimization, Crop, Model, Diversification, Soil.**

1. Introduction

With the help of mathematical optimization techniques, crop diversification is a process that simulates complex soil–plant relationships, which in turn determines the most beneficial crop patterns. To simulate the soil–plant systems, a computer-based model with a new mathematical optimization technique is an effective tool to facilitate crop diversification planners to make sound decisions prior to each crop season. An objective of crop diversification is to produce various crops instead of only one or two and select the crop in such a way so that it gives maximum production with minimum investment.

A plausible reason for diversification can be attributed to the fact that under multiple cropping systems, crops not only compete for nutrients but can mutually benefit each other. However, such agronomic benefits of crop diversification include improvement in soil fertility, tendency to reduce diseases, weed and insect build up and possibility to reduce erosion. Parallel to this farmer will get more experience for growing more than one crop. Moreover positive impact will be on the performance and production of another crop in the region.

Optimization techniques are generally utilized for taking care of complex handy issues in asset portion, transportation and coordination’s, venture choice, arranging and scheduling. Although these problems are well-known in manufacturing and business sectors, there exist similar optimization problems in agricultural systems such as crop selection [2], country-wide crop planning [4], irrigation planning [5], vegetable production [6], and sugarcane transportation [7]. As seen in these papers, the optimization problems were formulated as mathematical programming models and then solved using a variety of optimization methods. These models range from single to multi-objective, and from direct to non-straight forms. The optimization methods used in the studies range from conventional methods to computational intelligence (CI) techniques such as genetic/evolutionary algorithms.

Computer engineers using information technologies, such as evolutionary algorithms, will play an important role in natural resource management and crop production to meet the new challenges. An EA is a search procedure that uses random choice as an effective means of directing a highly exploitative search through a numerical coding of a given parameter space.

We propose an evolutionary algorithm to solve the optimal crop selections for a particular type of soil. Evolutionary algorithms have been used successfully to solve optimization problems, from the domain of operations research, in recent years. There are many favorable reasons for choosing evolutionary algorithm in solving optimization problems [3]. Due to the inherent parallelism, self-organization, adaptation and self-learning features of the EAs, they have been applied successfully to solve many problems where the classical approaches are either unavailable or generally lead to unsatisfactory results.

The paper is organized as follows. After introduction, the crop soil planning and problem model is introduced and its mathematical model is discussed. In Section 3, Materials and methods has been discussed. Solving the crop-planning model has explained in section 4. In the end result and discussion are summarized.

2. Crop-Soil Planning and Problem Model

In this section, we introduce a crop-soil planning issue. Cropping arranging is identified with numerous elements, for example, type of land, yield rate, climate conditions, and accessibility of the agricultural information sources, crop demand, capital accessibility and the expense of yield. A portion of these variables are quantifiable and can be evaluated. In any case, factors like rainfall, climate condition, surge, twister, and other normal catastrophes are hard to anticipate. Nonetheless, if the accessible data can be used appropriately, it might give profitable. The yield rate, the expense of generation, and the return from crop are elements of soil attributes (fertility and other soil factors), area, the product being delivered, cropping pattern and strategy (crop being produced and their sequence, water system, non-water system, and so on). Our main focus in this paper will be the utilization of land for appropriate crops. For a solitary cropped land, there are various alternative crops from which the crop to be developed in a year might be picked. Correspondingly there are a wide range of blends of yields for double cropped and triple-cropped lands. Distinctive combinations give diverse yields. To provide guidelines for crop diversification, an optimization model developed. Mathematically speaking, it is possible to write optimization problems in the generic form

Minimize

$$\mathbf{x}\in R^d \qquad f_i(\mathbf{x}),\ (i = 1, 2, \ldots, M), \tag{1}$$

$$\text{Subject to} \qquad h_j(\mathbf{x}) = 0,\ (j = 1, 2 \ldots J), \tag{2}$$

$$g_k(\mathbf{x}) \le 0,\ (k = 1, 2, \ldots, K), \tag{3}$$

Where $f_i(\mathbf{x})$, $h_j(\mathbf{x})$ and $g_k(\mathbf{x})$ are functions of the design vector

$$\mathbf{x} = (x1, x2 \ldots xd)^T. \tag{4}$$

Here the components x_i of $\mathbf{x}$ are called design or decision variables, and they can be real continuous, discrete, or a mix of these two.

The functions fi ($\mathbf{x}$) where i = 1, 2. . . M are called the objective functions or simply cost functions, and in the case of M = 1, there is only a single objective. The space spanned by the decision variables is called the design space or search space R_d, whereas the space formed by the objective function values is called the solution space or response space. The equalities for h_j and inequalities for g_k are called constraints. It is worth pointing out that we can also write the inequalities in the other way, ≥0, and we can also formulate the objectives as a maximization problem. In a rare but extreme case where there is no objective at all, there are only constraints. Such a problem is called a feasibility problem because any feasible solution is an optimal solution.

Model Development

Inputs

Subjects:

n crop suitable for production

m a crop combination made up from n

o soil type

Attributes:

k1	number of alternative crops Kharif season
k2	number of alternative crops for Rabi season
$K1_m$	a crop in each m for Kharif Season, m =1, . . ., k1
$K2_m$	a crop in each m for Rabi Season, m =1, . . ., k2
YR_{nmo}	yield rate that is the amount of production per unit area for crop n of crop combination m in land type *o*
VCP_{nmo}	variable cultivation cost required per unit area for crop n of crop combination m in land type o
MP_n	market price of crop n per metric ton
B_{nmo}	gross margin that is the benefit that can be obtained per unit area of land from crop n of crop combination m in land type o
S_o	*available land type o*
A	area suitable and available for crop n when o=1
X_{nmo}	area of land to be cultivated for crop n of crop combination m in land type o

Output: The best crop selection fulfilling the stop criteria.

Objective Functions

First objective Function is to maximize the farmer's income per acre according to the yield rate for crop n of crop combination m in the land type o for Kharif season.

$$\text{Maximum } Y1_{Kharif} = \sum_{n=1}^{K1} \sum_{m \in k1f} YR_{nm(o=1)} MP_{nm(o=1)} \quad (1)$$

Second objective Function is to maximize the farmer's income per acre according to the yield rate for crop n of crop combination m in the land type o for Rabi season.

$$\text{Maximum } Y1_{Rabi} = \sum_{n=1}^{K2} \sum_{m \in k2f} YR_{nm(o=1)} MP_{nm(o=1)} \quad (2)$$

Third objective function is to minimize the variable cultivation cost required per unit area for crop n of crop combination m in land type o for Kharif season.

$$\text{Minimum } Y2_{Kharif} = \sum_{n \in k1f}^{K1} VCP_{nm(o=1)} \quad (3)$$

It will be minimum if land is suitable for a crop, if land is not according to the type of crop then value of this function will be more which will not suit to the farmer.

Fourth objective function is to minimize the variable cultivation cost required per unit area for crop n of crop combination m in land type o for Rabi season.

$$\text{Minimum } Y2_{Rabi} = \sum_{n \in k2f}^{K2} VCP_{nm(o=1)} \quad (4)$$

Checks

Price Constraint: Price is a major constraint as outcome of any crop in terms of money depends on the market price per ton.

$$\sum_{n \in k1k2f}^{K1K2} MP_n \qquad (5)$$

After the selection of the land for a crop, market price will be the deciding factor in selection of a crop. A farmer will go for a crop which will have more price than others if production parameter is equal.

Land Constraint: Land used for the production of the crop should be suitable according to specific crop.

$$\sum_{n \in k1k2f}^{K1K2} X_{mo(n=1)} \qquad (6)$$

This constraint plays a major role in selection of a crop.

3. Materials and methods

In this section mechanism to select a particular crop for a given piece of land will be explained. There are number of crops available in the market and according to season crops are classified into two groups: Kharif and Rabi [1]. So selected combinations of the crops will be within the group only. To select an optimum crop for the given land, it depends on various factors such as production of that crop for that type of land (will give more yield if land is suitable for that crop), market price etc. So in this way first aim is to find out suitable piece of land for a selected crop. In this paper, we will consider two objectives: to maximize farmer's income per acre and minimize variable cost for crop production. One can achieve these two objectives only if a piece of land is suitable for a crop. This means that the chemical and physical properties of the soil suits the growing conditions for a particular crop, then that crop will give good yield in that type of soil. This can be possible by comparing the pre-request growing soil conditions for that crop and properties of that piece of land. If required conditions of the crop are matching with land this means that soil will be suitable for a crop. So in this way less fertilizers and others manures will need to get good crop production, ultimately variable cultivation cost will be less. Mathematically one can explain this by using below mentioned function.

$$F(x) = \sum_{b=1}^{t} f_b(x) \qquad (7)$$

Here $f_b(x)$ is a b^{th} objective function having t number of objectives.

3.1 Data Sets

3.1.1 Crop- Soil data

To develop a model one need the record of various required crops and different types of the soil data. As we have already discussed that crops are classified into two groups: Kharif and Rabi seasons.

Table 1: Crop-Soil mapping

Sr. No.	Crops	pH Value [8][9]	EC(deciSiemens/metre) [10]	Salinity Class [11][12]
1	Wheat	5.5-6.5	4-8	Slightly Saline
2	Cotton	5.5-6.5	2-4	Very Slightly Saline
3	Paddy	5.5-6.5	4-8	Slightly Saline
4	Corn	5.5-6.5	2-4	Very Slightly Saline
5	Barley	5.5-6.5	8-16	Moderately Saline
6	Peanuts	5.5-6.5	2-4	Very Slightly Saline

7	Sugarcane	5.5-6.5	2-8	Very Slightly Saline
8	Beans	5.5-6.5	0-2	Non Saline
9	Tomato	5.5-6.5	2-4	Very Slightly Saline
10	Potato	5.5-6.5	0-2	Non Saline

From the above given Table 1, one can check the required soil for a particular type of crop. By giving the weights to the different parameters of the soil we will be able to find out the sequence of the crops to be selected for field according to their production. For showing in the number system Salinity classes are defined as:

Slightly Saline=1

Very Slightly Saline=2

Moderately Saline=3

Non Saline=4

We can get the record of more crops for more dataset by getting the data of the physical properties of the soil. It depends on the need and diversification factors to include more crops. In the next sub-section the information of the variable cost and market price of the different crops is given.

3.1.2 Variable Cost and Market Price

Other parameters which play an important role is market price and variable cost (Includes expenditure of seed & seed treatment, Manures & fertilizers, Pesticides, Weedicides & Fungicides, Irrigation, Man power etc). Variable cost which directly or indirectly depends on the type of soil. If type of soil is suitable for a particular crop then variable cost will be less. So here main concern is main product value (market value). So by comparing the market value of all the crops and type of soil one can predict the suitable optimum crop by apply this proposed algorithm.

Table 2: Comparative Enterprise Budget of Kharif Crops, 2016

Crop	**Average Yield (q/acre)**	**Gross Returns** (Rs /acre)	**Total Variable Costs** (Rs /acre)	**Returns Over Variable Costs** (Rs /acre)
Paddy	29	42050	16733	25317
Basmati	14	29575	17968	11607
Maize	20	28500	15249	13251
Bt Cotton	10	43025	26103	16922
Desi Cotton	9	40320	18089	22231
Sugarcane Planted	334	103780	56120	47660
Sugarcane Ratoon	250	78650	29851	48799
Groundnut	10	41300	18466	22834
Bajra	15	21825	12138	9687
Moong	4.7	23595	11873	11722
Mash	3.6	17650	11577	6073
Arhar	5.8	30075	12783	17292

Soybean	7	19400	12758	6642
Sesame	2.7	13690	9568	4122

Note: The enterprise budgets are based on P.A.U. recommendations [13]

Table 3: Enterprise Budgets of Rabi Crops 2016-17

Crop	**Average Yield** (q/acre)	**Gross Returns** (Rs /acre)	**Total Variable Costs** (Rs /acre)	**Returns Over Variable Costs** (Rs /acre)
Wheat	20	36500	13807	22693
Barley	16	22600	9541	13059
Winter Maize	32	46600	20096	26504
Spring Maize	29	42625	19096	23529
Gram	7	25760	14618	11142
Lentil	5	18260	10917	7343
Field Pea	7.5	21375	12594	8781
Summer Moong	4.5	22665	11571	11094
Summer Mash	4.25	20856	12388	8468
GobhiSarson	7	24150	12579	11571
Toria	5	17000	11435	5565
Sunflower	7.9	30020	13967	16053
Linseed	4.7	16345	13782	2563
Mentha	50 Litre Oil	50000	24593	25407
Celery	5.5	26400	15230	11170
Fennel	4.5	24750	10246	14504
Coriander	2.75	15125	11200	3925

Note: The enterprise budgets are based on P.A.U. recommendations [13]

Gross Returns, total variable cost, returns over variable cost of different crops per acre are given in the table 2 and table 3 according to the kharif and Rabi seasons. By applying the proposed algorithm on this dataset (physical properties of soil, Gross returns, variable cost), one can suggest appropriate crop for a specific field to the farmer. A sequence order of the different crops can be shown as an output according to the maximum returns over the variable cost.

4. **Solving the crop-planning model**

There are more than 30 crops which can be grown in the fields of the Indian Punjab. Crops are divided in two major categories Kharif and Rabi. So depending upon the season one can give the suggestion of the appropriate crop. According to the given algorithm the crop selection depends on returns over variable costs. Further variable cost depends directly or indirectly on the soil properties. According to the given algorithm to check the appropriate crop for the field, first thing is to check the properties of the soil of the given field, this can be possible by checking the soil in the laboratory, once a farmer will get the soil report of the soil, then all those soils' parameters will be input for the algorithm. After processing the values of all those given soils' parameter, one will get the out of the crops in a particular sequence according to the production of the crops for the given soil. After getting the list of crops as an output from the algorithm, then that list will be input to the next step. In this step returns over variable costs will be calculated according to the previous years' variable cost and current market price of the crop. Whatever the list of the crops was in the first step that will be compared with the output of the second step. Now in the third step one will be able to get the list of crop which will be according to the soils' properties and returns over the variable costs. Now output of the third step will be the list of crop for those the given soil is suitable for the good production and will give maximum return according to the given market price & returns over the variable costs. In this way farmer can easily find out the suitable crop for his fields from production as well as price point of view by taking help from this GUI based model.

Results and discussion

By using soil parameters values to find out the suitable crop, one has to find the values of all the required soil parameters by testing the soil in laboratory. After getting the values of the soil's parameters, one will give input to the method for comparisons, on the basis of the values, a list of crops in the descending order will display as a shown in the graph. A farmer will select any crop from the first three four from the list. In this way a farmer can go for the crop which will take less water if farmer belong to the area where ground water as well as canal water is less. Crop diversification can be achieved by using this method, which is need of hour.

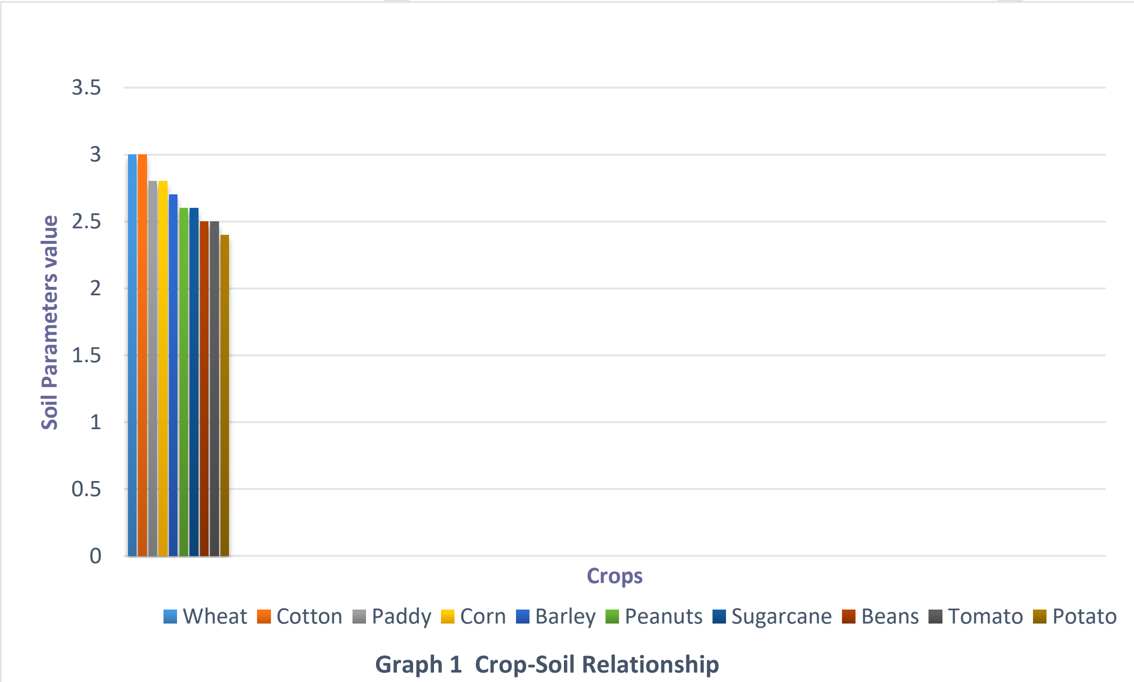

Figure 1: Crop-Soil Relationship

Conclusion

Crop diversification is regarded as a phenomenon which has attracted considerable interest among peasant farmers around the globe because of, as a potential risk management tool against uncertainty, Income and employment generation opportunity, Ability to reduce diseases, weed and insect build up, and Possibility to increase soil fertility and among others. So when a farmer has choice to select the appropriate crop for a particular soil then he can get the benefits of the points which ae discussed above. In this way Punjab's farmer can save ground water by growing the other alternative crops instead of paddy, other option he can get by using the above mentioned method. Using widely available optimization computer programs, the techniques farmers can get knowledge to implement the process.

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