Allocation of Agricultural Land To The Major Crops of Saline Track By Linear Programming Approach: A Case Study

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Abstract: Linear programming (LP) technique is relevant in optimization of resource allocation and achieving efficiency in production planning particularly in achieving increased agricultural productivity. In this paper a Linear programming technique is applied to determine the optimum land allocation to 10 major crops of the saline track of rain red zone using agriculture data, with respect to various factors viz. cost of seeds, cost of fertilizers/ pesticides, yield of crops, daily wages of labour and machine charges, selling base price of commodities, for the period 2009-2010. The proposed LP model is solved by standard simplex algorithm and Arsham's Push and Pull algorithm and the solutions are compared. A case study is carried out in the saline track of rain fed zone of Murtizapur Tahsil of Akola District, Maharashtra; India. It is observed that the proposed LP model is appropriate for finding the optimal land allocation to the major crops of study area.

Keywords: Land allocation, Simplex Algorithm, Push and Pull algorithm, saline track.

1 Introduction

The agricultural planning problems are important from both social and economical points of view. They involve complex interactions of nature and economics. Agriculture contributes to nearly 25% of Gross Domestic Product and about 70% of Indian population is dependent on agriculture for their livelihood. Agricultural planning is important in recent times due the increased demand of agricultural commodity because of population increase. Agricultural economics which deals with scientific planning for agricultural development has become an important area of specialization in agriculture. Optimal crop pattern with maximum profit is important information for agricultural planning using optimization models. Crop yield, man power, production cost and physical soil type are required to build the model. With optimization techniques available; such as Linear Programming (LP), Dynamic Programming (DP) and Genetic Algorithm (GA), it is LP model that is more popular because of the proportionate characteristic of the allocation problems. An agricultural planning in the saline track of the rain fed zone is most crucial task because an entire agriculture business depends upon the monsoon. In this paper, second section gives the review of the previous studies, the area of the study is explained in the third section, formulation of the model is presented in fourth section, the fifth section elaborates the application of the model to the proposed case study, solution of the problem is discussed in the sixth section and finally the conclusions are given in the seventh section of the paper.

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2 Review of Literature

These days LP is utilized by all sorts of firms in making decisions about establishment of new industries and in deciding upon different methods of production, distribution, marketing and policy decision making. Linear Programming (LP) is perhaps the most important and best-studied optimization problem. A lot of real world problems can be formulated as linear programming problems. The simplex algorithm developed by Dantzig [3], starts with a primal feasible basis and uses pivot operations in order to preserve the feasibility of the basis and guarantee monotonicity of the objective value. For LP models with ≥ or = type constraints, the problem of obtaining initial basic feasible solution is difficult as these problems lack feasibility at origin. The usual approach to solve such problems is to use either two-phase or Big-M method each of which involves artificial variables and the introduction of artificial variable brings artificiality in otherwise straightforward simplex method. H. Arsham [5] has proposed a new general solution algorithm, which avoids use of artificial variable in above stated situations and developed the comparison tool for Simplex and Push-Pull algorithms (SixPap [6]). H. Arsham *et.al*. [7] implemented the Push-Pull algorithm and standard simplex algorithm, for solution and comparison of computational techniques of general LPP, using. The push-pull algorithm, when used, brings no to a state of cycling in contrast to the simplex algorithm in presence of singular basis. V. I. Kustova [18] proved that each of the active constraints, which on some stage have become a strict inequality, can be neglected in subsequent computations. This statement is allowed, in one's turn, to establish fact that the number of arithmetic operations required for solving the general problem of linear programming is estimated by the value which is polynomially dependent on the dimension of the problem under scrutiny.
Radhakrishnan D [14] and Raj Krishna [15] proposed the LP technique for determining the optimal farm planning. The land use planning techniques and methodologies with different objectives, applications, and land uses have been identified by Santé I and Crecente R [16]. Another example is the combined application of General Information System and linear programming to strategic planning of agricultural uses was carried out by (Campbell et al. [2]). Keith Butterworth [10] suggested that in the current economic climate, linear

programming could well be worth reconsidering as a maximizing technique in farm planning. This particularly applies when it is used in conjunction with integer programming, which allows many of LP's problems to be overcome. Felix Majeke and Judith Majeke [4] used an LP model for farm resource allocation. They compared between the results obtained from the use of the LP model and the traditional method of planning and observed that the results obtained by using the LP model are more superior to that of obtained by traditional methods. A LP crop mix model for a finite-time planning horizon under limited available resources such as budget and land acreage, the crop-mix planning model was formulated and transformed into a multi-period LP problem by Nordin Hj. Mohamad and Fatimah Said [13] to the maximize the total returns at the end of the planning horizon. Ion Raluca Andreea and Turek Rahoveanu Adrian [9] suggested LP method to determine the optimal structure of crops, different methods which take into account the income and expenditure of crops per hectare were used for optimizing profit. They observed that, after applying the econometric model the profit rose to 143% and costs reduced to 81%. Andres Weintraub and Carlos Romero [1] analyzed the use of operations research models to assess the past performance in the field of agricultural and forestry and to highlight current problems and future directions of research and applications. In the agriculture part, they concentrated on planning problems at the farm and regional-sector level, environmental implications, risk and uncertainty issues, multiple criteria, and the formulation of livestock rations and feeding stuffs. Studies in optimum resource allocation using LP approaches have largely been attempted in many countries (Tanko L. et.al. [17]).

3 Area of Study: Saline Track

The saline track is the region in which the soils have excessive concentration of natural soluble salts, mainly of chlorides, sulphates and carbonates of calcium, magnesium and sodium (Krishisanvadini [11]). In these soils, the exchangeable sodium percentage is greater than 15 as a result the pH is more than 8.5. The electric conductivity (EC) is below 4 ds/m. Because of the high sodium content, both the clay and organic matter are dispersed, and the result is close packing of the soil particles and reduced pore space, permeability to water and aeration. The soil is medium to deep black with good fertility. Under field conditions the following symptoms will be seen:

a) On drying, shallow cracks are developed at the surface and soil becomes very hard and compact. The clods become extremely hard and difficult to make suitable tilth for sowing seeds.
b) Due to the low hydraulic conductivity, the water does not move down quickly and remains standing on the surface in a muddy condition for a long period.

The water type from wells and bore-wells in this region is also saline. Due to the salinity in soil as well as in water this type of soil is not suitable for irrigation. This type of soil is found in some parts of Akola, Amravati and Buldana districts of Maharashtra, (India) which is termed as saline track. In this area an agriculture business totally depends upon monsoon.

4 Formulation of Land Allocation Model

The LP model for agricultural land allocation problem has been formulated by considering the period of a year. The total time period is divided into number of seasons according to the climatic and environmental conditions which are assumed to normal. The first season from June to October and the second season from September end to March- April.

4.1 Notations

The description of notations used to build the model is given below;

- c_i The i^{th} major crop for cultivation $c = 1, 2, , ,C$; $s = 1, 2$.
- s_i The i^{th} season s_1 = First season (Kharip); s_2 = Second season (Rabi)
- X_{sc} The area of land used for cultivation of crop c in season s (= 1,2). (Hectares)
- T_s Total area of land available (hectares) for cultivation in s^{th} season.
- L_{sc} Land required for major crop c in season s.
- Y_{sc} Average yield in quintals per hectare of crop c in season s.
- TY_c Total yield target of crop c in quintals.
- W_{sc} Requirement of labours per hectare for crop c in season s.
- AW_s Expected labours availability in season s. (in man- days)
- MH_{sc} Average machine hours per hectare for crop c in season s.
- TMH_s Expected total machine hours available in season s.
- CPF_{sc} Cost of pesticides and fertilizers for crop c in season s. (Rs. per hectare)
- $TAPF_s$ Expected total amount available for pesticides and fertilizer. (in Rs.)
- NP_{sc} Net profit from crop c in season s in Rs. per hectare.
- SC_{sc} Cost of Seed as per the standards. (Rs. per hectare)
- C_s Total number of crops cultivated in season s.
- U_{sc} Proportion of land used in season s_1 and reused in season s_2.

4.2 Normal Conditions for The Model Formulation

The normal conditions to develop the model for the study area are stated as follows;

1. The monsoon starts at most by the mid of the June.
2. At least 15-40 mm of rain during a week.
3. No heavy rain from the last week of September to October end.
4. No heavy rain in the months of February and March.
5. No shortages of labors during pre harvesting, harvesting and post-harvesting periods.
6. No shortages of quality seeds and fertilizers.

4.3 Formulation of Objective function and Constraints

i. Objective Function

For maximization of Net Profit: The decision maker has to allocate the total available land to the crops so that the total profit will be maximum. Thus the objective function is formulated as follows;

Maximize $Z = \sum_{s=1}^{2} \sum_{c=1}^{C} NP_{sc} X_{sc}$ (1)

ii. Formulation of Constraints

The constraints from C_1 to C_8 are formulated as under;

C_1. For the total Yield: The objective of the decision maker will be to maximize the expected total yield from the crops. This constraint will be formulated as the sum of the product of area under the crop and estimate of yield per unit area of the crop in the given season should be greater than expected total yield from all crops. This constraint is as;

$$\sum_{s=1}^{2} \sum_{c=1}^{C} Y_{sc} X_{sc} \geq \sum_{c=1}^{C} TY_c \quad (2)$$

C_2. Labour Requirement: The labour is required the throughout the year for agricultural purposes. This constraint is formulated as, the sum of the product of estimated number of labours required and area of the crop 'c' in the season 's' should be less than the total number of labours available throughout the year.

$$\sum_{s=1}^{2} \sum_{c=1}^{C} W_{sc} X_{sc} \leq \sum_{s=1}^{2} AW_s \quad (3)$$

C_3. Machine-hours: The machines are needed for various tasks in agriculture viz. ploughing, sowing, cultivating, harvesting, tilling etc.. The total number of machine-hours required for various crops in season s should not exceed the total machine–hours available in the season. Thus this is expressed as

$$\sum_{s=1}^{2} \sum_{c=1}^{C} MH_{sc} X_{sc} \leq TMH_{sc} \quad (4)$$

C_4. Cost of Pesticides and fertilizers: The regular doses of pesticides and fertilizers are required to get maximum yield from the crop. The amount for this purpose being limited, this constraint is formulated as;

$$\sum_{s=1}^{2} \sum_{c=1}^{C} CPF_{sc} X_{sc} \leq TAPF_s \quad (5)$$

C_5. Availability of cultivable Land: The total land available for cultivation is fixed and limited. Thus the allocation of land to all crops in the season must not exceed total cultivable land. This imposes the constraint as;

$$\sum_{c=1}^{C} X_{sc} \leq T_s \quad (6)$$

C_6. 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 costs. Thus this constraint is stated as;

$$\sum_{s=1}^{2} \sum_{c=1}^{C} SC_{sc} X_{sc} \geq 0 \quad (7)$$

C_7. Constraint on usage of area in season 1 and season 2: Farmers allocate the total available land to the crops which grow in first season s_1 out of which some fixed predetermined area of land is used for short period crops. Let it be U_{cs}% of the total cultivable land and the same land is reused for the crops in the second season s_2. It means that farmers allocate U_{cs}% of total land to crops viz. Green Gram (Moong), Soya bean and Black Gram (Urid). (Generally U_{CS}= 0.395). Thus this imposes the constraint as;

$$X_{13} + X_{14} + X_{16} \leq U_{sc} * T_{sc} \quad (8)$$

$$X_{13} + X_{14} + X_{16} - X_{21} - X_{22} = 0 \quad (9)$$

C_8. Upper/Lower Boundaries for Area under the crop: The decision maker can fix the lower and/or boundaries for the area under crops in the season in such a manner that an economical requirement of farmers as well as the food requirement of the society is satisfied. These constraints can be written as;

$$X_{sc} \leq L_{sc} \quad s = 1, 2 \quad c = 1, 2,, , ,10 \quad (10)$$

and/or

$$X_{sc} \geq L_{sc} \quad s = 1, 2; \quad c = 1, 2, , , 10 \quad (11)$$

5. Case Study

The saline track of the Murtizapur Tahsil, district Akola, of Maharashtra (India) is taken as the study region to demonstrate the model. The tahsil consists of 165 villages and its geographical area is 789.43 sq. km. out of which 783.93 sq. km. is rural and 5.50 sq. km. the urban area. The total population of the rural area is 167312. The geographical region of this tahsil can be divided into two parts viz. saline and non saline areas. Our study is restricted to saline area only. In the study area, the agriculture totally depends on the monsoon and this region falls in assured rain fall zone and receives monsoon during June to October. The average annual rain fall in the study area is 714.1 mm spread over 44 rainy days in normal condition. The total area for cultivation purpose is 68595.19 hectares out of which 4403.811 hectares of area are irrigated. Thus the area under cultivation considered for study is 64191.379 hectares. Mainly there are two seasons for agriculture in the state of Maharashtra. The first season of crops is from June to October, termed as Kharip, the second season from October/November to April, termed as Rabbi. The main crops in the first season are Cotton, Jowar, Arhar (Tur, a type of pulses), Green Gram (Moong), Soya bean, Black Gram (Urid), Sunflower, Safflower (Karadi), while Gram and wheat are the major crops taken in second season. The crops of Green Gram (Moong), Soya bean, Black Gram (Urid) are short period crops i.e. 90 to 110 days. Therefore the land used for these crops is again used for the various crops in the second season viz. gram and wheat. Hence the total area under gram and wheat will be equal to the total area under the crops Green Gram (Moong), Soya bean and Black Gram (Urid). The data regarding the production of crops (qtl./hectare), use of land (hectare), requirement of labor (man-days/hectare), requirement of machinery (hrs./hectare), and cash (Rs.) requirement for all crops throughout the year have been collected from the various sources such as the Revenue Department of the Murtizapur tahsil, Directorate of Economics and Statistics, APMC Murtizapur, Department of Agriculture Zillah Parishad, Akola, PDKV Akola and personal surveys with the training and visit supervisors and the farmers. The set of variables , estimates of various factors and the values of right hand side constants for building the model are presented in the table (1), table (2) and table (3) respectively.

Table No. (1): Table of Variables

Crop Variable	Cotton $X_{1,1}$	Arhar (pulses) $X_{1,2}$	Green-Gram $X_{1,3}$	Soya bean $X_{1,4}$	Jowar $X_{1,5}$
Crop Variable	Black Gram $X_{1,6}$	Safflower $X_{1,7}$	Sunflower $X_{1,8}$	Gram $X_{2,1}$	Wheat $X_{2,2}$

Table No. (2):- Estimates of the Various Factors

Crop	Estimates of various factors.					
	NP_{sc}	Y_{sc}	W_{sc}	MH_{sc}	CPF_{sc}	SC_{sc}
Cotton	13563.50	11.25	123	4	5394	3625
Arhar	13648.50	9.25	85	4	3555.75	980
Green Gram	8302.75	10.75	119	5.75	3776.25	1625
Soya bean	6356.75	11.25	111	5.5	3776.25	1800
Jowar	5124.00	23.25	76	7.25	2326.25	850
Black Gram	4580.25	8.25	101	5.75	3447	1625
Safflower	4471.50	13.6	43	5	2462.5	670
Sunflower	5048.75	10.85	67	3.75	2181.25	1775
Gram	13992.85	11.65	32	3.75	3016.25	5400
Wheat	3250.25	9.75	31	3.75	2187.5	1687.5

Table No. (3):- Estimates of RHS Constants.

Sr. No.	Constraint	RHS Value
1	Production (quintals in lakhs)	10.85
2	Labour requirement (man-days in lakhs)	70.45
3	Machine utilization (hrs. in lakhs)	4.20
4	Fertilizers and Pesticides (Rs. crores)	31

6. Solution of the Model

The final LP model for land allocation problem in the study area comprises from equation (1) to equation (11), as in the Appendix. The solutions of model by Standard Simplex algorithm using Lingo [12] and by Push- Pull algorithm using Six-Pap [6] are presented in Table No. (4).

Table No. (4):- Table of Solutions (All figures are in hectares**)**

Crop	Variable	Algorithm Used		Allocation of land (in %)
		Push-Pull	Simplex	
Cotton	$X_{1,1}$	13791.55	13791.55	21.49
Arhar	$X_{1,2}$	8643.606	8643.606	13.47
Green Gram	$X_{1,3}$	10250.75	10250.75	15.97
Soya bean	$X_{1,4}$	11604.34	11604.34	18.08
Jowar	$X_{1,5}$	9500.000	9500.000	14.8
Black Gram	$X_{1,6}$	3500.500	3500.500	5.45
Safflower	$X_{1,7}$	4297.746	4297.746	6.7
Sunflower	$X_{1,8}$	511.6349	511.6349	0.8
Gram	$X_{2,1}$	25355.59	25355.59	39.5
Wheat	$X_{2,2}$	0.000000	0.000000	0.0
Iterations		20	11	

7. Conclusions

It has been observed, from previous studies that for some of the LP problems Push-Pull algorithms take less number of iterations as compared to Standard simplex algorithm while for some LP problems Standard simplex algorithm takes less number of iterations as compared to Push-Pull algorithms. In the present study we proposed LP model for optimum land allocation to the 10 major crops of the study area. The solutions are obtained by Standard Simplex algorithm and by Push-Pull algorithm. It has been observed that Push-Pull algorithm takes 20 iterations while the Standard Simplex algorithm takes only 11 iterations to find an optimum solution to the proposed model. Thus Standard Simplex algorithm saves 9 iterations over Push-Pull algorithm while solving the proposed model. The total land used in the first season is found to be 62100.1269 hectares which is less by 2091.2631 hectares than the land available for cultivation in the first season. The maximum profit achieved is Rs. 905217869 and the total cost required for seed is Rs. 250481524. The proposed land allocation plan to the major crops so as to maximize the net profit in the study area is 21.49% of land to cotton, 13.47% of land to arhar (pulses), 15.97% of land to Green-gram, 18.08% of land to Soya beans, 14.8% of land to Jowar, 5.45% of land to Black gram, 6.7% of land to safflower, 0.8% of land to sunflower, 39.5% of land to Gram and no land allocation to wheat. Finally we conclude that the proposed model is appropriate for land allocation to the major crops of the study area and also an algorithm which holds good for a particular problem may not be efficient for the slightly modified or different problem.

7.1 Appendices

A: LP model for land allocation in the study area.

$$\text{Max } Z = \sum_{s=1}^{2} \sum_{c=1}^{C} NP_{sc} X_{sc} \quad \text{Subject to}$$

1. $11.25X_{11}+9.25X_{12}+10.75X_{13}+11.25X_{14}+23.25X_{15}+8.25X_{16}+13.6X_{17}+10.85X_{18}+11.65X_{21}+9.75X_{22} \geq 1085000$
2. $123X_{11}+85X_{12}+119X_{13}+111X_{14}+76X_{15}+101X_{16}+43X_{17}+67X_{18}+32X_{21}+31X_{22} \leq 7045000$

3. $4X_{11}+4X_{12}+5.75X_{13}+5.5X_{14}+7.25X_{15}+5.75X_{16}+5X_{17}+3.75X_{18}+3.75X_{21}+3.75X_{22} \leq 420000$
4. $5394X_{11}+3555.75X_{12}+3776.25X_{13}+3776.25X_{14}+2326.25X_{15}+3447X_{16}+2462.5X_{17}+2181.25X_{18}+3016.25X_{21}+2187.5X_{22} \leq 310000000$
5. $3625X_{11}+980X_{12}+1625X_{13}+1800X_{14}+850X_{15}+1625X_{16}+670X_{17}+1775X_{18}+5400X_{21}+1687.5X_{22} \geq 0$
6. $X_{11}+X_{12}+X_{13}+X_{14}+X_{15}+X_{16}+X_{17}+X_{18} \leq 64191.39$
7. $X_{11}+X_{12}+X_{15}+X_{17}+X_{18} \leq 38835.79$;
8. $X_{13}+X_{14}+X_{16} = 25355.59$
9. $X_{13}+X_{14}+X_{16}-X_{21}-X_{22} = 0$;
10. $X_{15} \geq 9000.5$
11. $X_{13} \geq 10250.75$;
12. $X_{16} \geq 3500.5$;
13. $X_{15} \leq 9500$

7.2 References

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