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LINEAR PROGRAMMING PROBLEM (LPP) AND GEOGRAPHIC INFORMATION SYSTEM (GIS): A JOINT VENTURE TO OPTIMIZE LAND UTILITY

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Abstract. This paper is focused on the application of Linear Programming (LP) in combination with a Geographic Information System (GIS) in planning agricultural land-use strategies. A recent study described the advantages that could be achieved by combining LP models with geographical information systems (GIS) in the context of land-use planning. The integration of these two technologies follows approach: (1) a GIS is utilized to assemble data for the aggregate land-use alternatives; (2) the data are used as input to an LP model which determines the optimal land-use pattern as measured by the selected objective function and subject to all requisite constraints.
Keywords: Geographic Information System (GIS), Linear Programming (LP), Simulation, Optimization Techniques, Variable Transformation.

Introduction

Geographic Information System (GIS) simply described as any system that captures, stores, analyzes, manages, and presents data that is linked to location. The assessment of costs and benefits plays an important role during decision making concerning the implementation of GIS [1]. This paper describes different categories of benefits which can be accrued by introducing GIS and Linear Programming Problem (LPP) [2]: efficiency benefits, operational, strategic, and external benefits. Due to urbanization, Industrialization, and other demands land area for agricultural purpose rapidly going to decrease day by day. This will harmful to countries like India, where most of the life is depend upon agriculture. If necessary and effective actions are not taken immediately, situation would become more and worst in nearby future. Therefore, in this study an attempt will be made to develop a model based on GIS integrated with LP model that deals with land use development plan. Here GIS for land utility planning problem. GIS is used for selection of different types of land. Then land is converted to other form for its proper utility-that is source land is converted into target land. Expenditure incurred in developing land, labors, technical requirements etc are calculated along with net return and profit [3]. Then model is formulated as LPP to obtain an optimal solution.

Model formulation with GIS

A GIS can be considered as a tool for the integration and analysis of geographically- referenced data. More efforts should therefore be devoted facilitating the integration of spatial models and spatial methods of analysis.

Let us consider following land types and available land area: Waste land (A_1 ha), Grass land (A_2 ha), Forest land (A_3 ha), Single Crop land (A_4 ha), Double crop land (A_5 ha). To increase utility of land area for upgraded purpose that yields optimality in terms of employment and profit, one form of land area is converted into another type of land area. That is Waste land is to be converted into grass land or Waste land is to be converted into Forest land and so on. Following table shows Area matrix of land use from one form to another form, area is given in terms of hectors.

LP is a technique for calculating the optimal return from, the proposed infrastructure for land use development or any development plan in general. Linear programming makes it possible to obtain the optimal solution of the problem in order to make the objective function maximum. Linear programming is able to give a synthetic approach to complex situations. The linear programming has been structured to solve the problem of a case study of land transformation.

The results and problem structure are discussed in the next section, before that an out look of the necessity for integrating the GIS along with analytical model has been elaborated in the following section.

Along with conversion of different land type, employment factor is also taken into consideration after defining area required to be converted and investment per hectors. Following table shows employment and return in terms of profit earning for different conversion of source land.

Following table presents decision variables that are to be determined using LP techniques. First letter of decision variable denote source land while second letter denotes target land to be converted.

Problem formulation and Solution Procedure using GIS and LP

After gathering the necessary information about the objective function, constraints and coefficients a model can be constructed for the problem. For this exercise a simple matrix is sufficient, however more complication can be reached with LP problems with up to several hundred decision variables and constraints. The table1.1 summarizes the possible transitions from one land use to others, including the possible remaining land unchanged. Land that is double cropped is considered to be stable. On the other hand transformation from the single crop-land is possible only to double crop- land because of the intensity of land use in the area. With the information obtained from the GIS analysis, as well as from the economic data, the input matrix can be specified as shown in Problem 1 and Problem 2. The main objective of the present exercise is to maximize the profit and labor returns from new allocation of the land use. The coefficient of the objective functions, are the number of employees or the amount of investment for each land use. Constraints are related with the land available for transformation, namely forest land, waste- land, grassland, single crop- land and double crop- land.

Reviewing all these aspects integration of GIS and mathematical models are very much necessary and is what we wish to do in our study.

Problem 1:

This problem is formulated as LP to maximize profit earned after conversion of land from one form to another form using GIS. Then LP is solved by SOLVER or TORA software *[See Problem 1]*

It is assumed, for both problems, that shifting cultivation land has been merged into the forest- land area for the problem under study and water bodies are not taken in to account for land use transformation or development scheme. Characteristics for each type of land studied with the help of GIS, based on ground water, soil type and slope of the land.

Problem 2: This problem is formulated as LP to maximize (increase opportunity) employment after conversion of land from one form to another form using GIS. Then LP is solved by SOLVER or TORA software *[See Problem 2]*

Due to technical constraints-like forest policies that do not allowed to take 25% of total area for development, slope of land, soil conditions etc are ignored from problems formulated under study. The proposed study can be implemented on some imaginary data sets. These data sets were created so as to be as close as possible to real world situation in developing countries like India. The model can be well supported to a data set that could be derived using simulation techniques.

Conclusion

The present study reveals that GIS with LP could be apply for determination of decision variables that are best suited for an optimize utility of different types of land. The model carried out is able to depict that LP is a valuable tool for modeling the land use with the GIS framework. It provides objective criteria for the different land use where different goals are being considered. LP is also a flexible method for generating different planning scenarios, and with the help of LP multiple relationships between the decision variables and the constraints can be interpreted.

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Problem 1:

Objective Function

$Max\{p_1ww+p_2wg+p_3wf+p_4ws+p_5wd+p_2gg+p_3gf+p_4gs+p_5gd+p_3ff+p_4fs+p_5fd+p_4ss+p_5sd+p_5dd\}$

subject to Constraints:

Waste land:

$ww+wg+wf+ws+wd < W$

Grass land:

$gg+gf+gs+gd < G$

Forest land:

$ff+fs+fd < F$

Single cropland:

$ss+sd < S$

Double cropland:

$dd < D$

Financial constraints:

$l_{11}ww+l_{12}wg+l_{13}wf+l_{14}ws+l_{15}wd+l_{22}gg+l_{23}gf+l_{24}gs+l_{25}gd+l_{33}ff+l_{34}fs+l_{35}fd+l_{44}ss+l_{45}sd+l_{55}dd < B$

Where,

W=total waste land to be converted into required target land,
G= total grass land to be converted into required target land,
F= total forest land to be converted into required target land,
S= total single crop land to be converted into required target land,
D= total double crop land,
B=total budget allotted

Problem 2:

Objective Function

Max

$\{n_1ww+n_2wg+n_3wf+n_4ws+n_5wd+n_2gg+n_3gf+n_4gs+n_5gd+n_3ff+n_4fs+n_5fd+n_4ss+n_5sd+n_5dd\}$

Constraints:

Waste land:

$ww+wg+wf+ws+wd < W$

Grass land:

$gg+gf+gs+gd < G$

Forest land:

$ff+fs+fd < F$

Single cropland:

$ss+sd < S$

Double cropland:

$dd < D$

Financial constraints:

$l_{11}ww+l_{12}wg+l_{13}wf+l_{14}ws+l_{15}wd+l_{22}gg+l_{23}gf+l_{24}gs+l_{25}gd+l_{33}ff+l_{34}fs+l_{35}fd+l_{44}ss+l_{45}sd+l_{55}dd < B$

Where, W, G, F, S, D, and B defined as in Problem 1.

Table 1.1: Area matrix of land use from one form to another form

From/ To	Waste	Grass	Forest	Single	Double
Waste		A_{12}	A_{13}		
Grass	-	A_{22}	A_{23}	A_{24}	A_{25}
Forest	-	-	A_{33}	A_{34}	A_{35}
Single	-	-	-	A_{44}	A_{45}
Double	-	-	-	-	A_{55}

Table 1.2: Investment required per unit hectare area for land-use

From/To	Waste	Grass	Forest	Single	Double
Waste	-	I_{12}	I_{13}	I_{14}	I_{15}
Grass	-	I_{22}	I_{23}	I_{24}	I_{25}
Forest	-	-	I_{33}	I_{34}	I_{35}
Single	-	-	-	I_{44}	I_{45}
Double	-	-	-	-	I_{55}

Table 1.3: Suitable area of four types of land for conversion or development

SOURCE LAND	TARGET LAND	AREA (in hectors)	INVEST MENT
Waste land (W)	Grass land(WG)	A_{12}	I_{12}
Waste land (W)	Forest land (WF)	A_{13}	I_{13}
Grass land (G)	Forest land (GF)	A_{23}	I_{23}
Grass land (G)	Single Crop (GS)	A_{24}	I_{24}
Grass land (G)	Double Crop (GD)	A_{25}	I_{25}
Forest land (F)	Single Crop (FS)	A_{34}	I_{34}
Forest land (F)	Double Crop (FD)	A_{35}	I_{35}
Single Crop (S)	Double Crop (SD)	A_{45}	I_{45}

Table1.4: Job or profit return from different land-uses per ha

Variable	Employees/profit per ha
Waste land	n_1/p_1
Grass land	n_2/p_2
Forest land	n_3/p_3
Single Crop land	n_4/p_4
Double Crop land	n_5/p_5

Table1.5: Decision Variables for land use transformations

From/to	Waste	Grass	Forest	Single	Double
Waste	-	wg	wf	ws	wd
Grass	-	gg	gf	gs	gd
Forest	-	-	ff	fs	fd
Single	-	-	-	ss	sd
Double	-	-	-	-	dd