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A GOAL PROGRAMMING FORMULATION IN NUTRIENT MANAGEMENT OF FERTILIZERS USED FOR RUBBER PLANTATION IN TRIPURA

NABENDU SEN
ASST. PROFESSOR
DEPARTMENT OF MATHEMATICS
ASSAM UNIVERSITY
SILCHAR

MANISH NANDI
RESEARCH SCHOLAR
DEPARTMENT OF MATHEMATICS
ASSAM UNIVERSITY
SILCHAR

ABSTRACT

Natural rubber is the dominant cash crop of Tripura. Proper nitrogen, phosphorus and potassium applications to the soil are necessary to increase the production of latex and improve the Socio-economic position of the planters. Application of nutrients to the soil is commonly done by using fertilizers. In this paper, a goal programming model is formulated for nutrient management by determining the optimum fertilizer combination for rubber plantation in Tripura.

KEYWORDS

Linear goal programming, fertilizer combination, priority level, optimization.

INTRODUCTION

Most of the soil in the North Eastern region are highly degenerated due to shifting cultivation and heavy nutrient removed by thatch grass. In general, available phosphorus and potassium levels are low but the available magnesium is high. Based on this, a separate Fertilizer recommendation with slightly higher levels of N (nitrogen), P (phosphorus) and K (potassium) was formulated for the main field in the North Eastern region where the state Tripura belongs. Healthy rubber tree growth requires continuous supply of all essential nutrients from soil. Under the agro-climatic conditions, rubber plants after planting takes about seven years to attain tappability in most cases. The fertilizer requirements of rubber during the period of immaturity depend to a great extent on the cultivation practices, such as mulching the plant bases during the initial years and the establishment and maintenance of leguminous ground covers in the field. These cultivation practices will result in the improvement of the soil conditions and availability of plant nutrients, particularly nitrogen. The general fertilizer recommendation for rubber is based on the results of the fertilizer experiments conducted by the Rubber Research Institute of India on rubber of different age groups.

It is clear that planning rubber trees has widespread benefits. Rubber based agro-forestry involves a complex and diverse cropping system that combines the growing of rubber and other agricultural crops in the area in a sustainable manner. The rubber tree Hevea-Braziliens's was first introduced as a crop for plantation agriculture many years ago from the wilderness of the amazan jungles.

Application of N-P-K higher than the required level are likely to cause diverse effects on plants and result in a substantial decrease in their yields. Hence, for sustainable production of latex, it is necessary to produce optimum fertilizer combination for nutrient application to the soil. By doing so, damage to the soil's health is minimized. This results in increased production of latex and as a result, improves the economic position of the planters. There may be several objectives in nutrient management and thereby optimum fertilizer combination problems. Basic objective is achievement of nutrient requirements and minimization of cost.

The goal programming (GP) technique in solving agro-forestry management problems involving multiple objectives has become a widely used approach in Operation Research studies (Romero, 1986). The increasing popularity of GP and usefulness for decision-making policies has been aimed at optimizing agricultural land and other natural resources. GP technique can be used to address the problem of determining an optimum-cropping pattern by considering several goals in agricultural planning and management. Wheeler and Russell (1977) used a GP model to analyze the plantation of a farm in the United Kingdom. Ghosh (1993, 1995) presented a model for the allocation of land under cultivation for production of crops in different seasons in a year. Ghosh, Sharma and Mattison (2005) used a model for nutrient management for rice production. Also several studies have been used in natural resources planning (Romero, 1986), livestock ration formulation (Rehman and Romero, 1984, 1987), sugar beet fertilizer combination problems (Minguez, 1988).

In this paper, a priority based linear goal programming technique has been used to obtain the nutrient requirement for rubber plantation by determining the optimum fertilizer combination.

MODEL FORMULATION

The general priority based GP model as defined by Ignizio, 1976 can be stated as follows:

Find $X(x_1,x_2,.....,x_N)$ so as to

Minimize $P_1(w_{i1}^- d_{i1}^- + w_{i1}^+ d_{i1}^+)$,

Minimize $P_2(w_{i2}^- d_{i2}^- + w_{i2}^+ d_{i2}^+)$,

.

.

.

Minimize $P_j(w_{ij}^- d_{ij}^- + w_{ij}^+ d_{ij}^+)$,

.

.

.

Minimize $P_J(w_{iJ}^- d_{iJ}^- + w_{iJ}^+ d_{iJ}^+)$, i= 1,2,.....,m,

Subject to

$F_i(X) + d_i^- - d_i^+ = b_i$, i= 1,2,.....,m,

and

w_{ij}^-, w_{ij}^+, d_{ij}^-, d_{ij}^+, d_i^-, d_i^+, $X \geq 0$,

for i= 1,2,....,m; j= 1,2,.....,J,

where $f_i(X)$, i= 1,2,...,m, is the ith function (linear) of decision vector X, b_i is the aspiration level of the ith goal, P_j(j= 1,2,...,J; J≤m) is the jth priority factor assigned to the set of goals that are grouped together in the problem formulation, d_i^-, d_i^+ are the under and over-deviational variables corresponding to the ith goal, w_{ij}^- and w_{ij}^+ are the numerical weights associated with the under and over-deviational variables d_{ij}^- and d_{ij}^+ at the priority level P_j. Here, $d_{ij}-$ and d_{ij}^+ are renamed for the actual deviational variables d_i^- and d_i^+, respectively.

To formulate the model for the problem, the model variables, constants and coefficients are defined as follows.

Decision variables:

x_{in} = Amount of fertilizers (n= 1,2,....,N) in the mixture and i= 1,2,...,7(year)

Coefficients and constants:

C_{in} = unit cost for fertilizers x_{in} (n= 1,2,...,N) in the mixture and i= 1,2,...,7(year)

$A_{in}^{(q)}$ = unit amount of nutrient, q(q= 1,2,..,Q) in fertilizer x_{in}

$L_i^{(q)}$ = Minimum limit of nutrient, q(q= 1,2,..,Q)

$U_i^{(q)}$ = Maximum limit of nutrient, q(q= 1,2,..,Q)

T_i = Total cost of fertilizer

Goal constraints:

(1) Total cost:

To avoid any types of unwanted expenditure, there should be an estimated fertilizer cost (T_i) for a year. The goal equation can be presented as

$$\sum_{n=1}^{N} C_{in}\, x_{in} + d_{i1}^- - d_{i1}^+ = T_i \text{ , } I = 1,2,...,7$$

(2) Minimum limit of nutrient:

To ensure a good yield from rubber plant, there should be, at least, a minimum amount of nutrient in the fertilizer combination. The goal equation can be presented as

$$\sum_{n=1}^{N} A_{in}^{(q)}\, x_{in} + d_{i(q+1)}^- - d_{i(q+1)}^+ = L_i^{(q)} \text{ , } i = 1,2,...,7 \text{ and } q = 1,2,...,Q$$

(3) Maximum limit of nutrient:

To avoid any excess application of nutrient in the fertilizer combination, there should be a maximum limit for each nutrient in the combination. The goal equation can be presented as

$$\sum_{n=1}^{N} A_{in}^{(q)}\, x_{in} + d_{i(Q+q+1)}^- - d_{i(Q+q+1)}^+ = U_i^{(q)} \text{ , } i=1,2,...,7 \text{ and } q = 1,2,.....,Q$$

Application:

Our fertilizer combination plan for rubber plant is for the North-Eastern state Tripura, India. Basically, four types of fertilizers are applied in soil. The fertilizers are Urea, Ammonium Phosphate (AP), Rock Phosphate (RP) and Muriate of Potash (MOP).

TABLE 1: DATA DEFINITION

Variable / Year(i)	Urea	Ammonium Phosphate(AP)	Rock Phosphate(RP)	Muriate of Potash(MOP)
1	x_{11}	x_{12}	x_{13}	x_{14}
2	x_{21}	x_{22}	x_{23}	x_{24}
3	x_{31}	x_{32}	x_{33}	x_{34}
4	x_{41}	x_{42}	x_{43}	x_{44}
5	x_{51}	x_{52}	x_{53}	x_{54}
6	x_{61}	x_{62}	x_{63}	x_{64}
7	x_{71}	x_{72}	x_{73}	x_{74}

Goal constraints

Total cost:

$$\sum_{n=1}^{4} C_{in}x_{in} + d_{i1}^- - d_{i1}^+ = T_i \text{ , } I = 1,2,...,7$$

i.e. $C_{11}x_{11} + C_{12}x_{12} + C_{13}x_{13} + C_{14}x_{14} + d_{11}^- - d_{11}^+ = T_1$

$C_{21}x_{21} + C_{22}x_{22} + C_{23}x_{23} + C_{24}x_{24} + d_{21}^- - d_{21}^+ = T_2$

.

.

$C_{71}x_{71} + C_{72}x_{72} + C_{73}x_{73} + C_{74}x_{74} + d_{71}^- - d_{71}^+ = T_7$

Minimum limit of nutrients:

$$\sum_{n=1}^{4} A_{in}^{(nit)}x_{in} + d_{i2}^- - d_{i2}^+ = L_i^{(nit)} \text{ , } i = 1,2,.....,7. \text{ (Nitrogen)}$$

$$\sum_{n=1}^{4} A_{in}^{(pho)}x_{in} + d_{i3}^- - d_{i3}^+ = L_i^{(pho)} \text{ , } i = 1,2,.....,7. \text{ (Phosphorus)}$$

$$\sum_{n=1}^{4} A_{in}^{(pot)}x_{in} + d_{i4}^- - d_{i4}^+ = L_i^{(pot)} \text{ , } i = 1,2,.....,7. \text{ (Potassium)}$$

Maximum limit of nutrients:

$$\sum_{n=1}^{4} A_{in}^{(nit)}x_{in} + d_{i5}^- - d_{i5}^+ = L_i^{(nit)} \text{ , } i = 1,2,.....,7. \text{ (Nitrogen)}$$

4

$\sum_{n=1}^{4} A_{in}^{(pho)} x_{in} + d_{i6}^{-} - d_{i6}^{+} = L_i^{(pho)}$, i = 1,2,.....,7. (Phosphorus)

$\sum_{n=1}^{4} A_{in}^{(pot)} x_{in} + d_{i7}^{-} - d_{i7}^{+} = L_i^{(pot)}$, i = 1,2,.....,7. (Potassium)

Priority level:

As per the decision-making environment, priority level of the problem can be defined as follows:

P_1: Minimize $(d_{i2}^{-} + d_{i3}^{-} + d_{i4}^{-})$

P_2: Minimize $(d_{i1}^{+} d_{i5}^{+} + d_{i6}^{+} + d_{i7}^{+})$

Therefore achievement function is

Minimize $Z = P_1(d_{i2}^{-} + d_{i3}^{-} + d_{i4}^{-}) + P_2(d_{i1}^{+} + d_{i5}^{+} + d_{i6}^{+} + d_{i7}^{+})$

SOLUTION OF THE FORMULATED MODEL

In this paper, we have formulated the model for the period of seven years when matured rubber tree will produce latex. On the basis of available previous data, the developed model can be tested. Solution may be achieved by manual calculation. But manual calculation is time consuming process and not so easy. So the use of software like LINGO, Excel-Solver will be more easy.

CONCLUSION

In this paper, the methodology (Goal Programming) for optimum fertilizer combination is an alternative to the traditional optimization technique based linear Programming. It may be useful for agro-forestry planners who can guide the planters for fertilizer combinations. In this paper, we attempt to deal with the nutrient management problem using Goal Programming technique. Our study can be applied to other sectors also having the similar environmental constraints. For different climatic conditions, some practical aspects may be included in the model.

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