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GOAL PROGRAMMING APPROACH TO AGRICULTURE IN AFRICA: CASE OF TEFF PLANTATION IN ETHIOPIA TO GET BALANCED AND ECONOMIC NUTRIENT MIX

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ABSTRACT

For sustainable crop production, adjacent fertilization practices based on concrete nutrient limitation and yield requirements for a given crop are judicious and economical[1]. Balanced fertilizers can help boost crop productivity by restoring soil conditions.A fertilizer mix is complete with the presence of nitrogen, phosphorous, potassium, sulfur, copper, zinc and boron (N-P-K-S-Cu-Zn-B). This study presents a preventive linear goal programming model for multi-objective nutrient management problem by defining an optimal plantation nutrient combination strong in Ethiopia's warm weather. A set of data was used to measure the efficiency and effectiveness of the proposed model. Formulation results mean that all goals have been achieved. With regard to the goal priorities, the proposed model is quite flexible.

KEYWORDS: *Balanced Fertilizer; Complete Fertilizer; Compost Management; Fertilizer Combination; Goal Programming, N-P-K-S-B Fertilizers; Nutrient Mix; Teff Production*

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INTRODUCTION

For human welfare and economic growth, agriculture is important. Teff is a food crop in Ethiopia that is very popular and common. Agricultural gross domestic product (GDP) in Ethiopia accounts for 41.6% of the total GDP. Ethiopia is one of the sub-Saharan African countries where severe depletion of soil nutrients limits agricultural crop production and economic growth.The annual net nutrient loss per hectare is estimated to be at least 40 kg N, 6.6 kg P and 33.2 kg K (Scoones and Toulmin, 1999)[14]. In Ethiopia, tef is grown on an area of approximately 3 million hectares, with tef and maize accounting for approximately 24.02 percent of the total area of the grain. This makes tef the country's first in area coverage among cereals (CSA, 2015).Tef's national average yield is approximately 1.64 tons per ha (CSA, 2015). One factor that contributes to low tefis yield low soil fertility and suboptimal fertilizer use (Ermiaset al., 2007)[18].

Teff (Eragrostistef (Zucc.) Trotter) is a cereal grown for thousands of years in East Africa as a food crop (D'Andrea 2008)[5]. It is an essential grain in all East African countries households. It is a staple food for most of the Ethiopian and Eritrean population.Teff is adapted to a wide variety of environmental conditions and widely grown under different rainfall, temperature and soil conditions from sea level to 2800 m above sea level (a.s.l.) (Seyfu 1997).It is grown on approximately 2.59106ha in Ethiopia and accounts for approximately 28% of the total area allocated to cereals (Anonymous 2010a), yielding approximately 20% of total cereal grain production and 17% of cereal crop residues annually (Anonymous 2010b; FAO 1987).

Soils contain nutrients, of course. The crops suffer from nutrient deficiency when nutrients are short in supply and struggle to grow to maturity. A number of sources among them can be used with fertilizers to supplement the nutrients in the soil.Fertilizers are simply planting nutrients used in agricultural fields to supplement the elements that are naturally found in the soil. However, fertilizers can pollute the environment and also have a negative impact on the final yields if not handled and used well.

Because of their effect on the convenience of nutrients for floras, consideration of soil chemical possessions is chief. Usually the use of lime and/or materials can change these possessions kindly. Absence of seven nutrients (N, P, K, S, Cu, Zn, and B) from Ethiopia[2].Nitrogen (N), phosphorus (P), potassium (K) and sulfur (S) are known as primary or macronutrients. This is because they are essential compared to extra nutrients by the plant in enormous volumes and is the supreme nutrients that are likely to be found in soil systems to limit plant growth and expansion.

Need of the Study

According to Nyathi and Campbell[14], althoughlivingcompost is typically vital in large quantities to withstand crop production and may not be available to small-scale farmers, hence the need for lifeless manure. Carsky and Iwua testified for the confidence result of applying inorganic foods to crop harvesting and crop upgrading[1].Usually used enrichers include urea (46-0-0-0), ammonium nitrate (34-0-0-0), urea (46-0-0-0), di-ammonium phosphate (18-46-0-0), triple superphosphate (0-46-0-0), ammonium monophosphate (11-48-0.2-0), ammonium superphosphate (5-19-0-0) and potash muriate (0-0-60-0). Generate need to use different mixtures of nutrients.Complete compost is prepared by mixing various fertilizers. The combination of DAP and Urea is the most common mix for teffmanufacturing. According to WakjiraTesfahun, the effects of NPS fertilizer on tef yield and yield components showed that compared to the combination of DAP and Urea, the mixed fertilizers would be promising to grow tef[2]. Secondary data was used for study purposes.

OBJECTIVES OF THE STUDY

To find the optimum nutrient quantity to prepare the complete fertilizer mix to:

- Minimize the underuse of the lower nutrient bound.
- Reduce the overuse of the largest amount of nutrients.
- Minimize total fertilizer content costs.

Formulation of Problem as Goal Programming Model

Goal programming is a technique of optimization to solve problems with multiple goals that are generally incommensurable and often conflict with each other in a horizon of decision making. In other words, target programming is a powerful tool for addressing a company's multiple and incompatible goals.

As Ignizio[19] said, in the early 1960s, Charnes and Cooper introduced Goal Programming (GP) to resolve the model of multi-objective mathematical software design. Charnes and Cooper[20] reviewed the design of goal software as a multi-objective study tool.Sharma and Bhatt[6], Schniederjans[21], Taha[12], Fazillah[4], Hassan and Mohammad Basir[5], and Hassan and Sahrin[8] used target programming in a variety of cases. Wheeler and Russell[13] used target programming in agricultural planning, while Ghoshet al.[8] formulated an objective programming model for nutrient management in West Bengal for rice production.Sharma and Girmay[1] formulated a compost management goal programming model with three macronutrients in Ethiopia for Teff planting. The GP model based on common importance (as defined by Ignizio[19]) can be described as follows:

The approach to formulating the model of goal programming is similar to the linear model of programming. The mathematical model is given as follows:

Minimize $\sum_{i=1}^{m} w_i \, (d_i^- + d_i^+)$

subject to

$\sum_{j=1}^{n} a_{ij} x_i + d_i^- + d_i^+ = b_i$, i = 1, 2, …, m

andx_j, w_i, d_i^-, $d_i^+ \geq 0$ for all i, j

The objective function mainly contains the variables of deviation (di^- and di^+) representing each goal or sub-goal.

Variables of decision:

X_n= content of the mixture offertilizer (n=1,2,..., m) (kg / ha).

Coefficients and Constants

C_n = unit cost for fertilizer x_n(n=1, 2,..., N) in (Birr / kg)

A_n= nutrient content r=1, 2,..., R in fertilizerx_n (percent)

U_r = upper nutrient limit r in fertilizer (kg / ha), where r is nutrient type

L_r = lower nutrient limit r in fertilizer (kg / ha), where r is nutrient type

Z = total fertilizer cost (Birr)

Note that Birr is the currency of Ethiopia.

Objective Constraints

In this model, three constraints are to be considered: total cost, lower and upper nutrient limits.

- Total cost constraint :$Z = \sum C_n X_n + d_1^- - d_1^+$
  An estimated fertilizer cost (Z) for a season should be available to avoid any kind of unwanted expenditure.
- Lower limit of the nutrient:$L_r = \sum A_n X_n + d_{i+1}^- - d_{i+1}^+$
  There is a lower nutrient limit in the fertilizer combination, where r is a type of nutrient, to ensure a good harvest from the tef crops. I = 1, 2, etc.
- Upper limit of nutrient:$U_r = \sum A_n X_n + d_{i+1}^- - d_{i+1}^+$
  To avoid excess nutrient application, in the combination of fertilizer, where r represents the type of nutrient, there is a maximum amount of nutrients..i = 6,…10

Model Application

Tef planting is done using conventional methods of planting. Conventional planting is the most common way to plant crops where the crop / seed are directly planted to the soil.

Tabular form for the fertilizers currently being used for teff agriculture in Ethiopia and their costs

Table 1

Variable	Fertilizer Name	N%	P%	K%	S%	Zn%	Cu%	B%	Price Birr/Kg
x_1	Urea	46	0	0	0	0	0	0	13.92
x_2	Triple Super phosphate (*TSP*)	0	46	0	0	0	0	0	23.52
x_3	Di-ammonium phosphate *(DAP)*	18	46	0	0	0	0	0	13
x_4	Ammonium mono phosphate	11	48	0.2	0	0	0	0	62
x_5	Ammonium Superphosphate	5	19	0	0	0	0	0	5.75
x_6	Muriate of Potash *(KCL)*	0	0	60	0	0	0	0	30
x_7	NPSB(nitrogen phosphorus sulfur boron)	48.8	37.7	0	7	0	0	1	13.25
x_8	Potassium Sulfate	0	0	43	18	0	0	0	14.75
X_9	Copper Sulphate	0	0	0	13	0	25	0	3.12
X_{10}	Zinc Sulphate	0	0	0	11	22	0	0	16.38

The complete fertilizer can be obtained by mixing different fertilizers as described in the table above by applying N–P–K-S-Cu-Zn-B(Nitrogen-Phosphorus-Potassium-Sulfur-Copper-Zinc-Boron).The Department of Agriculture recommends maximum and minimum requirements for these nutrients: 70–135 kg / ha of nitrogen, 75–125 kg / ha of phosphorus, 60–120 kg / ha of potassium, 75–175 kg / ha of sulfur, 2,75–11,2 kg / ha of copper, 4–9 kg / ha of boron, 2–50 kg / ha of copper. Data are collected from the *Farmer Association of Gombak* and *Petaling District* [4].

Tabel for the maximum and minimum requirements of fertilizer components to the soil

Table 2

Compound of Fertilizers	Upper Limit (Maximum Requirement) Kg/Ha	Lower Limit (Minimum Requirement) Kg/Ha
Nitrogen (N)	135	70
Phosphorous (P)	120	70
Potassium (K)	115	55
Sulfur (S)	105	30
Copper (Cu)	11.2	2.75
Zinc (Zn)	9	4
Boron (B)	50	2

- Total cost$Z = \sum C_n X_n + d_1^- - d_1^+$,, n = 1, 2, …, 7
- Lower limit of nutrients of nitrogen, phosphorus, potassium,sulfur and boron, n = 1, 2, …, 7

$L_N = \sum A_n X_n + d_2^- - d_2^+ = 70$,,

$L_P = \sum A_n X_n + d_3^- - d_3^+ = 70$

$L_K = \sum A_n X_n + d_4^- - d_4^+ = 55$

$L_S = \sum A_n X_n + d_5^- - d_5^+ = 30$

$L_{Cu} = \sum A_n X_n + d_6^- - d_6^+ = 2.75$

$L_{Zn} = \sum A_n X_n + d_7^- - d_7^+ = 4$

$L_B = \sum A_n X_n + d_8^- - d_8^+ = 2$

- Upper limit of nutrients of nitrogen, phosphorus, potassium, sulfur and boron, n = 1, 2, …, 7

$U_N=\sum A_nX_n + d_9^- - d_9^+ = 135$

$U_P=\sum A_nX_n + d_{10}^- - d_{10}^+ = 120$

$U_K=\sum A_nX_n + d_{11}^- - d_{11}^+ = 115$

$U_S=\sum A_nX_n + d_{12}^- - d_{12}^+ = 105$

$U_{Cu}= \sum A_nX_n + d_{13}^- - d_{13}^+ = 11.2$

$U_{Zn}= \sum A_nX_n + d_{14}^- - d_{14}^+ = 9$

$U_B=\sum A_nX_n + d_{14}^- - d_{14}^+ = 50$

Priority Structure

The deviation variables to be minimized are prioritized as follows:

P1: Minimize underutilization of lower limit of nutrients i.e; Min.$(d_2^- + d_3^- + d_4^- + d_5^- + d_6^- + d_7^- + d_8^-)$

P2: Minimize overutilization of upper limit of nutrients i.e; Min. $(d_9^+ + d_{10}^+ + d_{11}^+ + d_{12}^+ + d_{13}^+ + d_{14}^+ + d_{15}^+)$

P3: Minimize the total cost in fertilizer content i.e; Min. d_1^+

RESULTS

The model has been solved by using EXCEL Solver.

The optimum solution is:

NPSB (x_7) = 276.6393kg/ha

Potassium Sulfate(K_2SO_4) (x_8) = 267.4419 kg/ha

Total cost of combination of above fertilizers = 7610.24 Birr/ha

P1: Achieved

P2: Achieved

P3: Achieved

Since all$d_2^-, d_3^-, d_4^-, d_5^-, d_6^-, d_7^-,$ andd_8^- are zero, which means that there is no underspending of any nutrient, so the first priority is to minimize fertilizer overuse, the second priority is to achieve zero with all all $d_9^+, d_{10}^+, d_{11}^+, d_{12}^+, d_{13}^+, d_{14}^+andd_{15}^+$.Therefore there is no under-use and over-use of nutrients. Finally, as $d_1^+$is zero, the last cost goal is also achieved. Although the total cost does not decrease asd_1^- is also zero, which means that the crop can receive better nutrients at the same cost.

The cost of applying minimum 70 kg/ha Nitrogen, 70 kg/ha phosphorus, 55 kg/ha potassium, 30 kg/ha sulfur, 2.75 kg/ha copper,4 kg/ha zinc and 2 kg/ha boron is Birr 7610.24 per hector.

Therefore, all the priority objectives are achieved.

CONCLUSIONS

According to this study, the combination of N-P-K-S-Cu-Zn-B fertilizers is prudent and cost-effective compared to the mixture of DAP and Urea, which is the same economic but does not provide the required nutrients for the crop.The results of this study also support the study of WakjiraTesfahun [1] that “appropriate fertilization practices based on the actual limiting of nutrients and crop requirement for a given crop is economic and judicious use of fertilizers for sustainable crop production”.

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