Deterministic Optimisation
IE6560
Management of Crops

Project Report by

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Project Guide
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Problem Statement

Mr. Patil wants to do crop management. He owns 200 acre of Total farm in 4 pieces of land as 70 Acre 80 Acre 40 Acre and 10 Acre. Crop management is the group of agricultural practices used to improve the growth, development and the yield of the crop. Various costs included in the production of crops like cost of seeds, cost of fertilizers, cost of fresh water etc. Mr. Patil wants to do crop management for financial year 2020. Crops planted in 2019 are wheat, rice, sugar cane, beet root. He is planning to plant wheat, soybean, sugar cane, beet root in 2020.Cost of Water is 30Rs/Kiloliter and Cost of labor is 7500Rs

We plan to do crop management by

- Maximizing the profit
- Minimizing the total cost

Steps for getting the solution:

1. Define Decision variable

2. Define objective function

3.Define Constrains

4. Solve the objective function with respect to constrain in solver (Excel Solver)

Required data is given in following table

Table 1

Crop	Kg of Seeds required for 100 kg production	Cost Price of seeds /kg (Rs)	Requirement of fresh water (Kilolitre)	Production per Acre in (kg)	Selling price (Rs/100 kg)
Wheat	5	40	9	25	1525
Soybean	8	25	5	13	1600
Sugar Cane	3	40	10	35	1600
Beet root	8	35	7	20	1500

Table 2

Crop	Fertilizer (kg/100kg)	Cost of Fertilizers (Rs/kg)	Waste Product in terms of its production (%)
Wheat	35	220	12
Soybean	26	150	5
Sugar Cane	35	260	20
Beet Root	26	170	10

Table 3

Crop	Fertilizer Kg/100kg	Cost of Fertilizers (Rs/kg)	Waste Product in terms of its production (%)
Wheat	35	220	12
Soybean	26	150	5
Sugar Cane	35	260	20
Beat Root	26	170	10

Literature review

Article 1 - Sustainable Optimization of Agricultural Production: This paper presents a model for sustainable optimization of agricultural production. The model is a mathematical programming model, based on multi criteria techniques, and can be used as a tool for the analysis and simulation of agricultural production plans, as well as for the study of impacts of the various policies in agriculture. To achieve the optimum production plan, there should be maximization of gross margin and the minimization of fertilizers used. The constraints to be considered are total cultivation area, CAP constraints, market and other constraints, rotational and agronomic considerations, irrigations constraints. But the use of fertilizer and water use will come under the costs and not as decision variables. This proposed model was applied to the two regions of Thessaly, in central Greece. In both the regions, the optimum production plan achieves greater gross return, less fertilizers use, and less irrigated water use than the existent production plan. In this paper MCDM model is used for sustainable planning and the optimization of agricultural production.

Article 2 - The Use of Models in Optimizing the Field Crop Production in Agricultural Enterprise: This article refers to the use of resource capacities. The full use of resource capacities can increase economic efficiency and production. This will improve business strategies that uses all available resources to create the most profitable production. The main objective of this article is to maximize the profit using the available production resources. The production resources include land, mechanization, labor forces. The analyzed data on natural production and achieved production are not being used to a maximum and this have unsatisfactory economic results. The optimization of existing production structure will give better results naturally (yield) and economically (gross margin) also.

Article 3 - Soil and Crop Management Strategies: This article refers about the current agriculture scenario. Nowadays, population is rising because of that there is reduction in the amount of land. This is impacting on the current agricultural procedures to meet the increasing food demands. Due to increased demands, fertilizers and other chemicals are overused, which are worsening the surroundings. This intensive production without adherence to ecological sustainability has led to declining soil health, land degradation is severe environmental problems. In this paper, various soil and crop management strategies have been discussed. Reducing chemical usage such as fertilizers and pesticides could minimize greenhouse gases emissions and increase the soil health. Optimal solution of chemical usage as compared to the total demand will reduce the environmental problems like greenhouse effect.

Decision Variables: -

X_{ij} = **i** crop planted on the **j** crop land = 1

= 0 Otherwise

- where **i** = (1,2,3,4) 1=Wheat 2=Soybean and 3=Sugar cane 4=beat root
- **j** = (1,2,3,4) 1=Wheat 2=Rice 3=Sugar cane 4 =beat root

We have decision variable for Quintal of production of crops as following

- X_1: Total Quintals of Production of wheat
- X_2: Total Quintals of Production of Sugar cane
- X_3: Total Quintals of Production of beat root
- X_4: Total Quintals of Production of soybean

Decision variable for other cost

- Z_{ws} = Cost of waste Production
- Z_c=Cost of Seeds
- Z_l = Cost of labour
- Z_{wt}= Cost of Fresh water
- Z_f=Cost of fertilizer

Case 1

In Case 1 We are maximising profit so total profit required is,
Selling Price – Cost of Seeds – Other cost (labour waste fertilizer water).

Objective Functions:
Profit = Selling Price – Cost of Seeds – Other cost (labour waste fertilizer water)

$\mathbb{Z}(Max) = 1525X_1 + 1600\ X_2 + 1600\ X_3 + 1500X_4 - Z_c - Z_l - Z_{ws} - Z_f - Z_{wt}$

Table 4: Selling Price of crops

Crop	Selling price (Rs/100 kg)
Wheat	1525
Soybean	1600
Sugar Cane	1600
Beet root	1500

Constraints: -

1. Budget Constrain: -
   Mr. Patil has Budget of 40000 Rs
   So addition of all costs should be less than 40000 Rs
   $Z_c+Z_l+Z_{ws}+Z_f+Z_{wt} <= 40000$
2. Cost of Seed: -
   In the Table We are given Kgs of seeds required for 100 kg production and Cost of seeds per kg
   So for 1 quintal of production of wheat required 5*40=200Rs so for X1 quintal it will require 200X1
   Similarly, finding the seed cost for other crops and adding it we get following constrain
   $200X_1 + 200X_2 + 120X_3 + 280X_4 = Z_c$
   $200X_1 + 2\ 00X_2 + 120X_3 + 280X_4 - Z_c = 0$

Table 5: Seed requirement and cost

Crop	Kg of Seeds required for 100 kg production	Cost Price of seeds /kg (Rs)
Wheat	5	40
Soybean	8	25
Sugar Cane	3	40
Beet root	8	35

3. Cost of Water: -
Cost of Water is Rs30/kltr
1 quintal of wheat required 9 kilolitre of water so X1 Quintal of water will require 9x1 amount of water so
Similarly, finding water requirements of other crops and adding them to get total required water
total water required is
$9X_1 + 5X_2 + 10X_3 + 7X_4$ Kilo litre of water
As cos of water is 30Rs/Kilo litre so total cost of water is
$270X_1 + 150X_2 + 300X_3 + 210X_4 = Z_{wt}$
$270X_1 + 150X_2 + 300X_3 + 210X_4 - Z_{wt} = 0$

Table 6: Water Requirement of crop

Crop	Requirement of fresh water (Kilolitre) for 100kg
Wheat	9
Soybean	5
Sugar Cane	25
Beet root	7

4. Cost of Labour :-
Labour requirement of for Total 200 acre of land is 7500Rs
$Z_l = 7500$

5. Total loss due to waste produced: -
Wheat produces 12% waste production of total so total waste produced by wheat is
$0.12*X_1$ (for X_1 quintal of production)
As selling price of wheat is 1525Rs per quintal so
$0.12*1525*X_1$= cost of waste for X1 quintal production of wheat
$183X_1 + 80X_2 + 320X_3 + 160X_4 = Z_{ws}$

Table 7: Crops and their waste production, selling price

Crop	Waste Product in terms of production of fertilizer (%)	Selling price (Rs/100 kg)
Wheat	12	**1525**
Soybean	5	**1600**
Sugar Cane	20	**1600**
Beet Root	10	**1500**

6. One type of crop on one land and it should not be repeated on other land: -

- $\sum_{j=1}^{3} X_{1j} = 1$
  - $X_{11} + X_{12} + X_{13}=1$
- $\sum_{j=1}^{3} X_{2j} = 1$
  - $X_{21} + X_{22} + X_{23}=1$
- $\sum_{j=1}^{3} X_{3j} = 1$
  - $X_{31} + X_{32} + X_{33}=1$

7. On one land one type crop should be planted: -

- $\sum_{i=1}^{3} X_{i1} = 1$
  - $X_{11} + X_{21} + X_{31}=1$
- $\sum_{i=1}^{3} X_{i2} = 1$
  - $X_{12} + X_{22} + X_{32}=1$
- $\sum_{i=1}^{3} X_{i3} = 1$
  - $X_{13} + X_{23} + X_{33}=1$

Table 8: Production by land

Land	**Production in 2019**	**Production option in 2020**
1	Wheat 80 acre	Wheat
		Soybean
		Sugar cane
2	Rice 40 acre	Wheat
		Soybean
		Sugar cane
3	Sugar cane 70 acre	Wheat
		Soybean
		Sugar cane
4	Beet Root 10 Acre	Beet Root

8. Total production of wheat: -
   Total land available for wheat production
   $80*X_{11} + 40*X_{12} + 70*X_{13}$
   So total production of wheat is

$0.25(80*X_{11} + 40*X_{12} + 70*X_{13}) = X_1$

i.e. $20X_{11} + 10X_{12} + 17.5X_{13} = X_1$

Similarly, total production of soybean is

$10.4X_{21} + 5.2X_{22} + 9.1X_{23} = X_2$

Total production of sugar cane is

$28X_{31} + 14X_{32} + 24.5X_{33} = X_3$

Total production of beet root is

$2X_{44} = X_4$

Table 9: Production option and their resources requirement

Production in 2019	**Production option in 2020**	**Resources requirement per acre in 2020**
Wheat-80 acre	Wheat	1
	Soybean	0.75
	Sugar cane	0.8
Rice -40 acre	Wheat	1.2
	Soybean	0.9
	Sugarcane	1.25
Sugar cane 70 acre	Wheat	0.8
	Soybean	1.1
	Sugar cane	1
Beet Root 10 Acre	Beet Root	1

Production per Acre in (kg)
25 (Wheat)
13 (Soybean)
35 (Suger cane)
20 (Beet Root)

9. Effect of fertility of soil due to previous year's production: -

Here, we have considered the previous year's production and the effect on fertility of soil on the particular crop. If we plant wheat in last year then production of wheat on that land will require same quantity of fertilizers i.e. $X_{11}= 1$

Similarly, $X_{21} = 1$ then 25% less fertilizer will be required if soybean is produced on wheat land

- Amount of fertilizer required for wheat is
  $35(1X_{11} +1.2X_{12} + 0.8X_{13})$
- Amount of fertilizer required for soybean is
  $26(0.75X_{21} + 0.9X_{22} + 1.25X_{23})$
- Amount of fertilizer required for sugar cane is
  $35(0.8X_{31} + 1.25X_{32} + 1X_{33})$
- Amount of fertilizer required for beet root is
  $26(1X_{44})$

10. Cost of fertilizer: -
    Fertilizer required for wheat if we plant on 1st land is 35*1*X11kg
    Cost of fertilizer if we plant wheat on 1st land 22*35*1*X11 =770X11
    Similarly, we found all cost of crop's fertilizer.
    - For wheat
      $770X_{11} + 922X_{12} + 616X_{13}$
    - For Soybean
      $292.5X_{21} + 351X_{22} + 487.5X_{23}$
    - For sugar cane
      $728X_{31} + 1137.5X_{32} + 910X_{33}$
    - For beet root
      $442X_{44}$
    - Adding all costs, we get Total cost of Fertilizer
      $770X_{11} + 922X_{12} + 616X_{13} + 292.5X_{21} + 351X_{22} + 487.5X_{23} + 728X_{31} + 1137.5X_{32} + 910X_{33} + 442X_{44} = Z_f$

Table 10: Fertilizer cost and requirement

Crop	**Fertilizer Kg/100kg**	**Cost of Fertilizers (Rs/kg)**
Wheat	35	22
Soybean	26	15
Sugar Cane	35	26
Beet Root	26	17

Solution:

X_1 (Quintals of Production of Wheat)	20
X_2 (Quintals of Production of Soybean)	9.1
X_3 (Quintals of Production of Sugar cane)	14
X_4 (Quintals of Production of Beet Root)	2
Z_c (Cost of Seeds)	8060
Z_{wt} (Cost of Water)	11385
Z_l (Cost of Labour)	7500
Z_{ws} (Cost of Waste)	9188
Z_f (Cost of fertilizer)	2837

Case 2

In case 2 We are minimising the cost
So total cost requiring for the production are
Cost of seeds, cost of water, Cost of labour, cost of waste, cost of fertilizer

Objective Function:
So New objective function is
$\mathbb{Z}(\text{min}) = Z_c + Z_{wt} + Z_l + Z_{ws} + Z_f$

Constrains:

Selling Price constrain:
Selling price for each quintal of crop is given so total selling price is
$1525X_1 + 1600\,X_2 + 1600\,X_3 + 1500X_4$

But it should be more than 40000
So,
$1525X_1 + 1600\,X_2 + 1600\,X_3 + 1500X_4 \geq 40000$

All other constrains are same, no need of budget constrain as are minimising the cost (the same equation of budget constrain).

Table 11: Crops and Their selling Price

Crop	Selling price (Rs/100 kg)
Wheat	1525
Soybean	1600
Sugar Cane	1600
Beet root	1500

Solution

X_1 (Production Wheat in Quintal)	17.5
X_2 (Production Wheat in Quintal)	10.4
X_3 (Production Wheat in Quintal)	14
X_4 (Production Wheat in Quintal)	2
Z_c (Cost of seeds)	7820
Z_{wt} (Cost of Water)	10905
Z_l (Cost of Labor)	7500
Z_{ws} (Cost of Waste)	8834.5
Z_f (Cost of Fertilizers)	2488

Conclusion and Recommendation

- Maximum profit from case 1 is Rs 31490 and total cost required for maximum profit is Rs.38970 so (selling price is 70460)
- Minimum cost from case 2 is Rs 37547.50. Selling price when cost is minimum Rs 68727.5 hence Profit when Cost is minimum Rs 31180. Detailed production comparison and costs ate given below in table
- There is a change in both the cases of crop planning i.e. production of crops in case 1 is different than production of crops in case 2 (crop planted on land). Changes in crops and their land is given below in comparison chart
- So, we recommend them minimum cost model because in that model profit is just decreased by 310Rs but cost is decreased by 1442.5Rs.

Variable	Case 2	Case 1
X_1 (Production Wheat in Quintal)	17.5	20
X_2 (Production Soybean in Quintal)	10.4	9.1
X_3 (Production Sugar cane in Quintal)	14	14
X_4 (Production Beet Root in Quintal)	2	2
Z_c (Cost Of seeds)	7820	8060
Z_{wt} (Cost Of Water)	10905	11385
Z_l (Cost Of Labor)	7500	7500
Z_{ws} (Cost Of Waste)	8834.5	9188
Z_f (Cost Of Fertilizers)	2488	2837

Case 1 Crops and their land	Case 2 crops and their land
X11 Wheat on Wheat land(land 1) X23 Soybean on sugarcane land (land 3) X32 Sugarcane on Rice land (Land 2) X44 Beetroot on Beetroot land (land 4)	X13 What on Sugarcane land (Land 3) X21 Soybean on Wheat land (Land 1) X32 Sugarcane on Rice land (Land 2) X44 Beetroot on Beetroot land (land 4)

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