Agriculture Optimization Based on Linear Programming and Python Algorithm: Take Sichuan Province as an Example

Kaiquan Fan[a]
SWUFE-UD Institute of Data Science, Southwestern University of Finance and Economy, 610000, China

Keywords: Linear Programming, Machine Language, Optimization, Agriculture.

Abstract: Food is the paramount necessity of the people. Increasing the yield of food is always the most significant thing for every country in the world. Only those countries that struggle improving their technology in planting planning obtain achievement and success in the fight against hunger and poverty. Blindly expanding the sown areas not only unduly takes up labor and land sources, but also may undermine the process of social industrialization. In this case, the best way to boost yield is to improve the level of resources utilization. Based on the agricultural data of Sichuan province from 2011 to 2022 and 3 types of crops taken as an example, this study constructs math model and use machine language to find the optimal solution of planting planning. The study innovates a universal model to analyze and optimize problems under multi-constrains. With increasingly more relevant and influential factors added and trained with more detailed data, more accurate and more mature the model is.

1 INTRODUCTION

Food shortage and hunger have become to a global problem. According to the report delivered by Food and Agriculture Organization (FAO) in 2024, the numbers of global undernourished population for 2019-2023 are respectively 581.3 million, 669.3 million, 708.7 million, 723.8 million and 733.4 million (Raphael et al., 2014). Even though it has tended to stabilize in recent 3 years, it had sharply increased by 26% from 2019 to 2023. Every country is trying their best to increase the production of food like using new technology in planting food crops. Only those countries that spare no effort to innovate and modernize their agriculture gain success in the struggle against hunger and poverty (Goncharova and Merzlyakova, 2021). With the development of some developing countries, increasingly more domestic agricultural land is going to be used for industrialization, blindly expanding the area of cultivated land is obviously not a proper method (Sofi et al., 2015).

Under these present circumstances, one of the most significant factors contributing to increase production is the optimization of resource usage. The optimization of land use structure represents a resource allocation approach that holistically integrates the economic, social, and ecological benefits of regional land utilization. Through the adjustment of land distribution in both quantitative proportions and spatial arrangements, this process aims to establish a balanced state between the supply and demand of land resources (Wu and Zhong, 2020).

Traditionally, crop planning was simply based on the farmers' thoughts and their own views. However, with the development of modern research, crop planning becomes more and more mathematical and scientific (Jain et al., 2018). France emphasized the importance of modeling in agriculture (France, 1988). Levkina highlighted the avail of mathematical modeling to assess economic benefit and analyze risks in agriculture (Levkina et al., 2019). Bhatia and Bhat reviewed that through optimizing farm resource allocation, the production and production efficiency shall increase (Bhatia and Bhat, 2020). Dixit and Tyagi delivered a fuzzy approach to analyze and handle the linear programming problems in agriculture, which is an abstract and microscopical way. Thus, quantization and rigorous analysis in such problems are still in need (Dixit and Tyagi, 2024). Algorithm design is also an essential part in solving linear programming. When making crop planning

[a] https://orcid.org/0009-0005-1237-4178

Fan, K.
Agriculture Optimization Based on Linear Programming and Python Algorithm: Take Sichuan Province as an Example.
DOI: 10.5220/0014324000004718

In *Proceedings of the 2nd International Conference on Engineering Management, Information Technology and Intelligence (EMITI 2025)*, pages 157-161
ISBN: 978-989-758-792-4

decisions, regional situations, constraints and the planning purpose can be constructed into a mathematical model, which is the core of optimization. To plan these functions and constraints as a whole and deal with it, the computer language is one of the most efficient and the most accurate tool. In past decades, computer have had a rapid and great progress, which provided people a convenient and swift way to solve linear programming problems (Dantzig, 2020).

In this backdrop, the present article aims to realize crops pattern optimization, handle the problem of planting insufficiency and maximize the resource usage under the given conditions. At theoretical and academic level, this study is an attempt to enrich the theoretical system of agricultural planning, deepen the theoretical integration of interdisciplinary approaches. And it is also expected to fill some gaps in the application of refined mathematical theories in agricultural planting planning, provide new ideas and methods for the improvement of agricultural planning theory. Moreover, it can promote the transformation of agricultural planning from the traditional empirical type to the scientific and precise type. And at practical level, it is also an attempt to improve the economic efficiency of agricultural production and provide the scientific basis for the formulation of agricultural policies.

Moreover, it is worth highlighting that this study designs Python algorithms to build mathematical models and solve problems. In addition, the study takes the agricultural planting situations in Sichuan province as an example to solve. And the actual data will be taken into calculation. Therefore, readers can clearly understand the key point and the mode of analysis in this research, and the real change of resource and benefit in agriculture through optimization.

2 METHODS

2.1 Data Source

The Agricultural data used in this paper comes from BEEDATA platform website, and it was provided by the official institution China's National Bureau of Statistics and Sichuan Provincial Bureau of Statistics. The data contains the detailed agricultural situation in Sichuan province during 2011 to 2022.

2.2 Data Introduction

The data used in the article contains 12 variables. Creating an algorithm to discuss the influence of each variable and optimize the agricultural structure in Sichuan province. And the names and explanations of each variable are shown in Table 1.

Table 1: Variables used in this article.

Variables	Logogram	Explanation
sown_area	xi	the area of each type of crop be sown
pesticide_cost	cp	the cost of pesticide per kilogram
pesticide_amount	p	the usage amount of pesticide
pesticide_per_unit	pu	the average usage of pesticides per km^2
pesticide_budget	Bp	the budget for purchasing pesticide
sown_area_of_crops	S	the total sown area of food crops
unit_plants_output	ui	Output of each crop per km^2
output	Y	the amount of crops yield
fertilizer_cost	cf	the cost of fertilizer per kilogram
fertilizer_amount	f	the usage amount of fertilizer
fertilizer_per_unit	fu	the average usage of fertilizer per km^2
fertilizer_budget	Bf	the budget for purchasing fertilizer
n_var	n	the number of variables
demand	di	the demand quantity of each food crop
sown_area	xi	the area of each type of crop be sown

When i = 0, 1, 2, it respectively represents grains, tubers and beans.

2.3 Method Introduction

The method used in this paper is linear programming simplex algorithm which is realized by python language. The main body of this algorithm is the mathematical model which contains a purpose function and several constraints. The ultimate goal is to maximize the output of crops. Therefore, the objective function to maximize can be built as:

$$\mathrm{Y} = \sum_{\mathrm{i}=1}^{\mathrm{n}} x_i \, \mathrm{u_i} \quad (1)$$

This means the total production (Y) should be maximized by increasing the production of each type of crops.

And the conditions to limit this purpose function are respectively the pesticide:

$$c_p p \le B_p \quad (2)$$

$$i.e.\ c_p p_u \sum_{i=1}^{n} x_i \le B_p \quad (3)$$

The cost in pesticide of crops should be less than or equal to the budget of pesticide (B_p).

The total sown area:

$$\sum_{i=1}^{n} x_i \le S \quad (4)$$

The sum of them should be less than or equal to the total area used to plant.

The fertilizer:

$$c_f f \le B_f \quad (5)$$

$$i.e.\ c_f f_u \sum_{i=1}^{n} x_i \le B_f \quad (6)$$

The cost in fertilizer of crops should be less than or equal to the budget of fertilizer (B_f).

The demand:

$$x_i \ge d_i \quad (7)$$

The production of each type of crops should satisfy the demand quantity of the public.

3 RESULTS AND DISCUSSION

3.1 Descriptive Analysis

The figure 1 is the histogram of pesticide usage amount from 2011 to 2019. The amount of pesticide usage has been decreasing during this period, and the amount is in the 46-62 thousand tons range. The average is 56.88 thousand tons.

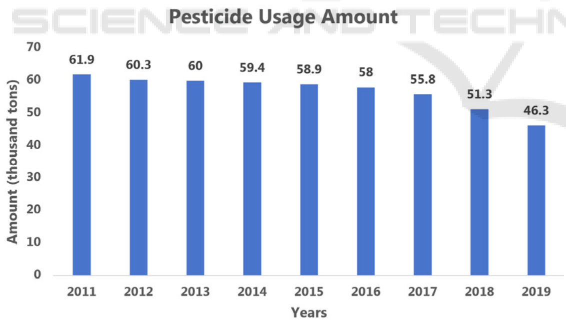

Figure 1: The histogram of pesticide usage amount (Picture credit: Original)

The figure 2 is the histogram of fertilizer usage amount of fertilizer from 2011 to 2021. The usage amount of fertilizer decreased slowly in this decade. The amount fluctuates from 2000-2500 thousand tons. The average is 2383.9 thousand tons.

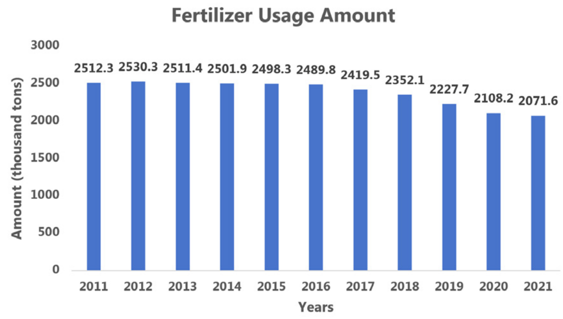

Figure 2: The histogram of total fertilizer usage amount (Picture credit: Original).

The figure 3 is the histogram of total sown area from 2011 to 2021. The average is 95.42 thousand square kilometers. The total sown area has been steadily increasing in recent years and reached the highest value, 99.999 thousand km^2, in 2021.

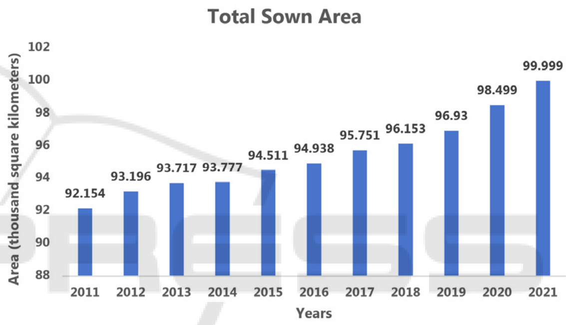

Figure 3: The histogram of total sown area (Picture credit: Original).

According to figure 1, 2, and 3, the average usage of pesticides and fertilizers per square kilometer can be calculated, which respectively are 0.5961 ton/km^2 and 24.9832 ton/km^2.

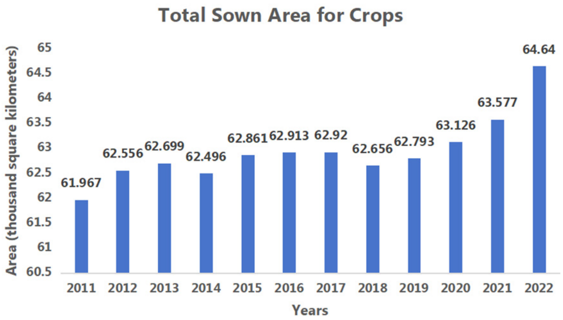

Figure 4: The histogram of total sown area for crops (Picture credit: Original).

The figure 4 is the histogram of total sown area for crops from 2011 to 2022. The amount of total sown area for crops rose and fell modestly, but there was an increasing tendency in total sown area for crops. The average is 62.934 thousand square kilometers.

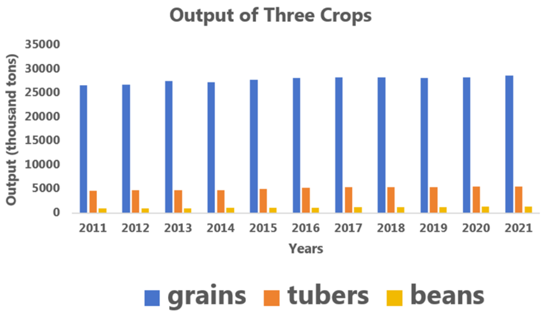

Figure 5: The histogram of output of grains, tubers and beans (Picture credit: Original).

The figure 5 is the histogram of output of grains, tubers and beans. The average of these three crops are respectively 27872.8, 5171.3 and 1171.1 thousand tons. The proportion of the three is approximately 25:5:1. Accordingly the minimum bound of demands can be set as the 60% of minimum output of all crops, which are respectively 16053.36, 2833.62 and 610.08 thousand tons.

The figure 6 is the histogram of sown area of grains, tubers and beans. The average of these three crops are respectively 45.36, 12.35 and 5.067 thousand square kilometers.

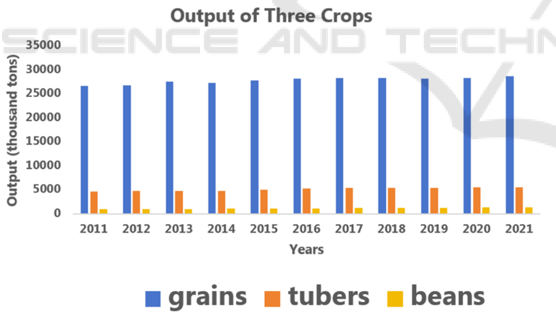

Figure 6: The histogram of sown area of grains, tubers and beans (Picture credit: Original).

The minimum demands quantity of each type of crops are set as the minimum amount in the data, which are respectively

According to these grams, the output per km^2 of each type of crops can be worked out which are respectively 314.5, 418.7 and 231.1 tons/km^2, whose sown areas are accordingly 85.07, 11.28 and 4.40 thousand km^2. In addition, the average cost of pesticide and fertilizer are respectively 40800 and 2628 yuan/ton.

3.2 Code Implementation

The math model can be translated into machine language into python. And this algorithm is based on a computing library of python which is gurobipy.

This algorithm is universal for majority situation. Once the data have been collected, users can input them into the code to find the optimal solutions.

The table 2 is the input data for every parameter. In this problem, the data come from the preceding analysis of this article. In other situations, users can only change the detailed values of following parameters to optimize different problems.

Table 2: The table of the input data for every parameter.

P	Value	P	Value
c_p	40800	c_f	2628
p	$p_u * x_i$	f	$f_u * x_i$
p_u	0.5961	f_u	24.9832
B_p	$c_p * 56880$	B_f	c_f*2383900
S	62934	n	3
u_i	[314.5,418.7,231.1]	d_i	[16053360,2833620 ,610080]

And the objective function is $Y = sum(x_i[i] * u_i[i]\ for\ i\ in\ range(n))$. The table 3 shows 4 constrains that limit this optimization model, which are respectively pesticide, fertilizer, sown area and demand.

Table 3: The table of 4 constrains.

Constrain	Value
Pesticide	sum(x_i[i] for i in range(n)) * p_u * c_p <= B_p)
Fertilizer	sum(x_i[i] for i in range(n)) * f_u * c_f <= B_f)
Sown area	sum(x_i[i] for i in range(n)) <= S
Demand	(x_i[i] * u_i[i] >= d_i[i] for i in range(n)

Through optimization by importing the gurobipy library, the solution could be found and shown in the following table 4.

Table 4: The table of output solution.

Parameters	Value
x_1(grains)	51044.07 km^2
x_2(tubers)	9250.03 km^2
x_3(beans)	2639.90 km^2

4 CONCLUSIONS

This study takes many factors which could influence the actual situation such as the pesticide budget, the fertilizer budget, the sown areas and demands for every crop. This article also focuses on the refinement of planting planning by applying the basic principles of linear programming. And the design of the algorithm improves the efficiency and the accuracy of planting planning. Theoretically and academically, this research endeavors to strengthen the theoretical framework of agricultural planning while enhancing the interdisciplinary theoretical convergence. This is also an attempt to make agricultural planting planning more scientific and refined. It also aims to address existing lacunae in applying refined mathematical theories to agricultural planting planning, offering innovative insights and methodologies for advancing agricultural planning theory. And it may provide a reference for the official department to formulate relevant policies. For further research, more relevant data and relevant factors should be taken into account. In the actual situation, there are plenty of different limits and constrains that influences the planning. More factors, more universal the model is. Trained with more data, the model will be more mature and accurate. And the results should be compared and the model should be adapted by futural training for more accurate and advanced results.

REFERENCES

Bhatia, M., Bhat, G. M. J. (2020). Linear programming approach-application in agriculture. *J. Emerg. Technol. Innov. Res,* 6(5), 155-157.

Dantzig, G. B. (2020). Impact of linear programming on computer development. *In Computers in Mathematics,* 233-240.

Dixit, P., Tyagi, S. L. (2024). A Fuzzy Approach to Linear Programming in Agriculture Land Allocation. *Journal of Computational Analysis & Applications,* 33(6).

France, J. (1988). Mathematical modelling in agricultural science. *Weed Research,* 28(6), 419-423.

Goncharova, N. A., Merzlyakova, N. V. (2021). Food shortages and hunger as a global problem. *Food Science and Technology,* 42, e70621.

Jain, R., Malangmeih, L., Raju, S. S., Srivastava, S. K., Immaneulraj, K., Kaur, A. P. (2018). Optimization techniques for crop planning: A review. *The Indian Journal of Agricultural Sciences,* 88(12), 1826-1835.

Levkina, R. V., Kravchuk, I. I., Sakhno, I. V., Kramarenko, K. M., Shevchenko, A. A. (2019). The economic-mathematical model of risk analysis in agriculture in conditions of uncertainty. *Financial and credit activity problems of theory and practice,* 3(30), 248-255.

Raphael, R. et al., (2014). Optimization of preparation conditions of activated carbon from agriculture waste utilizing factorial design. *Powder Technology An International Journal on the Science & Technology of Wet & Dry Particulate Systems.*

Sofi, N. A., Ahmed, A., Ahmad, M., Bhat, B. A. (2015). Decision making in agriculture: A linear programming approach. *International journal of modern mathematical sciences,* 13(2), 160-169.

Wu, Z. B., Zhong, F., (2020). Investigation on the Land Use Optimization Path under the Guidance of Implementation Evaluation: A Case Study of Shangluo Central City. *Financial and credit activity problems of theory and practice.*