Agricultural Land Use Planning Optimization adapt to Climate Change in Vietnam

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Abstract

Currently, the land area for agricultural production in Vietnam is decreasing due to urbanization and changing land use. The issue of agricultural land used how to use efficiency considering increasing the added value of land uses to bring high economic efficiency. There are many solutions to use land resources effectively; land use planning could be considered in terms of crop restructuring. However, when restructuring crops with many crops on agricultural land, the issue of area conversion for each crop is an issue that needs to be to policymakers in the rural agriculture sector. This paper presents the optimal agricultural land use approach towards increasing economic value significantly when facing to lack of water and climate change. The report also presents the results of applying the calculation model for a commune in Hung Yen province. The result of the research expressed the economic value of land increases meanwhile saving more water for other users.

Keywords: Land used, Land restructure, Economic optimal, Agricultural land planning.

1. Introduction

Currently, the land fund for agricultural production is decreasing due to urbanization and conversion of land use purposes in agriculture. Urbanization is happening increasingly rapidly, especially in urban peri-urban areas, narrowing the agricultural production area due to the change of use purpose to construct new urban spaces for industry, commercial services, and infrastructure.

Moreover, agricultural land has yet to be effectively planned and exploited in many places, and there needs to be a scientific and reasonable calculation of arable land use planning. According to the Prime Minister's Decision No. 1819/QD-TTg on approving the agricultural restructuring plan for the period of 2017 - 2020, it is also clear that it is necessary to continue to review and adjust the planning, the plan to transform the agricultural sector change the structure of crops and products in line with the advantages and market demands in the direction of increasing the value of agricultural land use shifting low-yield and low-productivity rice land to other more efficient and marketable crops or aquaculture suitable to local ecological conditions.

However, the problem of converting rice land to other crops also needs to be explicitly calculated to ensure the national food security goals. The conversion of rice to other crops brings high economic efficiency. It reduces water consumption for the agricultural industry, especially in abnormal weather conditions due to the effects of climate change. The task set for the farm sector in general and localities, in particular, needs a reasonable land planning strategy based on the transformation of crop structure with a high economic value per unit area. It also ensures adaptation to variable climate conditions, especially in the current situation of water resource depletion.

Optimizing land use will help improve land use efficiency, predict land constraints, and achieve maximum profitability (Zhang et al., 2012; Razali et al., 2014). . In addition, implementing optimal arable land planning will help maximize technology application and reduce land degradation (Hengki D. Walanggitan et al., 2012; Reza Sokouti and Davood Nikkami, 2017). The planning of agricultural land use will be good management of surface water for agricultural production (Hong Minh Hoang et al., 2014). Therefore, applying mathematical models to solve the problem of agricultural land use planning is necessary and practical with the current conditions.

Land use planning is one of the important contents of the State on land management, contributing to enhancing the effectiveness and efficiency of land management and use, serving socio-economic development, national defense, and security in the process of industrialization and modernization of the country (Nguyen Dinh Bong, 2006). . In terms of specific goals, land use planning and plans help closely manage the change of land use purpose for rice cultivation, serve as a basis for inspection, supervision, and protection of rice land area, ensuring security. National food (Phan Trung Hien and Nguyen Tan Trung, (2016). According to Nguyen Duc Minh (2004), ensuring food security is a central and strategic task in the policy of stability and development. However, in the production process, farmers are constantly exposed to double risks due to natural disasters and market risks, typically the situation of "losing the crop at a good price" or "getting a good price," hindering the expected livelihoods of farmers (Nguyen Quoc Nghi and Le Thi Dieu Hien, 2014; Vo Van Tuan and Le Canh Dung, 2015) In recent years, the effects of climate change have become increasingly difficult to predict. Reduce the sustainability of agricultural development and significantly affect people's livelihoods (Nguyen Hieu Trung et al., 2015). Natural anomalies, saltwater intrusion, and drought significantly affect rice production's lack of fresh water supply (Wassaman et al., 2004; Hong Minh Hoang et al., 2014). According to Pham Thanh Vu et al. (2016), natural changes such as saltwater intrusion and inundation reduce land suitability for agricultural production. The land for rice cultivation in the future tends to shrink; instead, the user types belong to the saline and brackish ecological zones. Besides, water storage activities for developing irrigation and hydropower upstream have changed the flow; the water source downstream is scarce, out of control, and increases the risk of saline intrusion (Tri et al., 2012; Monre, 2015). With many pressures and challenges from dangers from nature and the market, it is necessary to have tools to support in making decisions on land use and agricultural production planning. Supporting tools such as mathematical models have been effectively applied in managing the environmental resources of land, water, and agriculture.

The demand for water for domestic purposes and economic development components has a strong tendency to increase; however, Vietnam's surface water resources are abundant, and more than 50% are born outside the border and distribution. Uneven water resources in space and time will exacerbate the water supply and demand imbalance, especially with climate change. Our country's water used for agriculture accounts for 81%, 11% for aquaculture, 5% for industry, and only 3% for domestic use. In the coming time, with the speed of socio-economic development, the demand for water for other economic sectors is increasing, decreasing the amount of water supply for agriculture. It is forecasted that by 2030, the structure of water use will change according to the trend of Agriculture 75%, Industry 16%, and consumption 9%. Water demand will double, accounting for about one-tenth of river water, one-third of domestic water, and one-third of steady-flowing water. Therefore, by 2030, the amount of water supplied to agriculture will decrease significantly in quantity and quality. Thus, the agricultural sector in the locality needs to pay attention to this decline to incorporate appropriate land use planning strategies.

Therefore, it is necessary to study the scientific basis for land use planning to change the crop structure between different crops to bring about economic benefits and ensure the water supply of the irrigation system, especially considering the deterioration of water resources due to the effects of climate change and the increasing demand for water exploitation for the development of non-agricultural industries. The objectives of this study are: (i) Building a general optimization problem model in planning the conversion between crops in the condition of water resource depletion due to the influence of climate change; (ii) Developing a specific optimization problem for crop transformation based on building the optimal problem of economic benefits of crops, in the condition of the limited land fund and resource depletion water and local agricultural economic development conditions. The results of the thesis will be the scientific basis for policymakers and agrarian land planners in the process of rural restructuring towards increasing the value of agricultural production while ensuring food security goals—a national reality.

2. Study materials and methods

2.1. Study materials

Hai Trieu commune, Tien Lu district, Hung Yen province, now has two villages with a total natural area of 510.69 hectares with a population of over 6000 people. The commune is located south of the region, with the Luoc river running for 3.2km, adjacent to Thai Binh, inter-provincial road 39B, and road 200 along the commune.

The efficiency of land use types can be determined by surveying 603 households in Trieu Duong village and 567 homes in Hai Yen village (Table 1). According to the table on the current status of arable land, Hai Trieu commune focuses on producing six main crops: Rice, Sweet Potato, Potato, Maize, Elephant grass, and vegetables. The area planted for each crop type, currently focusing on rice cultivation, is 120.0 ha, and the lowest is the area for potato cultivation, which is only 1 ha.

Table 1: Area structure of crops in 2019.

No	Land use type	Area (ha)
1	Rice	120.0
2	Sweet potato	2.0

3	Potato	1.0
4	Vegetables of all kinds	15.9
5	Corn	10.0
6	Elephant grass	1.1

2.2. Study methods

2.2.1. Assumptions of the problem

To build a general optimization problem for optimal land use planning, it is necessary to have assumptions, to make a model of the problem:

(1) Only consider the problem of converting the number of cultivated areas of each annual crop, such as rice, maize, potato, cassava, produce, etc.

(2) The study has yet to consider the conversion between annual crops and perennial crops; the economic optimization problem will add elements of many years when planning to use annual crops for perennial crops.

(3) On an area of arable land considering the rotation and intercropping, it will be considered in terms of economic value over time as the crop and calculated in the net income of the main crop: for example, growing corn can be intercropped with vegetables or beans...

(4) The optimal target of economic benefits is calculated in 1 year for agricultural production.

(5) Constraints will be related to the overall planning and policies of each locality, food security policy (ensure provide a minimum area for growing rice and other food crops)

(6) The climate change factor is considered based on the reduction of water supply for agriculture (can be designed according to the scenarios of supply reduction).

(7) The local conditions of capital, labor, machinery and equipment, and fertilizer supply are all met because the market is considered competitive.

2.2.2. Objective function

$$\boldsymbol{Maximize\ TNTT} = \sum_{i=1}^{k} \boldsymbol{w_i \times n_i \times TNTT_i}$$

In which:

Self-created experiments: Total economic profit earned from agricultural production; Wi: Cultivated area of the crop i (ha); n_i: Is the number of crops in a year for crop i. TNTTi: Net income per hectare of the cultivated area i.

2.2.3. Constraints

Land constraints: the total cultivated area of crops does not exceed the total agricultural area of the locality.

$$\sum_{i=1}^{n} \boldsymbol{Wi \leq D};$$

Minimum land constraints: This depends on food security, as well as the influence of the type of cropland (for example, from low-lying land where only rice cannot be grown, 100 hectares of land. can grow rice, but of which 30 ha is lowland rice land that can only grow rice).

$$\boldsymbol{W_i \geq W_{\min i}}$$

Maximum Land Constraints: This depends on the soil quality to cultivate for each crop; for example, in 300 hectares of agricultural production, only 100 hectares of soil are suitable for rice cultivation.

$$\boldsymbol{W_{imax} \geq W_i}$$

Water irrigation supply constraints: It must be ensured that the total amount of water required at the focal point must be less than the potential of the water source at the corresponding time. The total amount of water to be irrigated for each crop must be less than the total amount of water supplied by the system, depending on the design capacity of the system:

$$\sum_{i=1}^{k} W_i \times n_i \times D_i \leq Dmax$$

In which: Wi: is the cultivated area of the crop i; Di: Water demand for 1 hectare of the harvest I; n_i: Is the sowing coefficient (number of crops per year of crop i); Dmax: Total amount of water supplied, due to system limitation, due to increasing demand for water for other purposes.

Value constraints: Values of the cultivated area must be non-negative.

$$W_i \geq 0, \forall\, i = 1..n$$

2.2.4. Optimal method

There are many solutions to the optimization problem; for the optimal mathematical model, this paper proposes to use the GAMS optimization software to solve the problem with the advantage that the software is designed independently from the top. Input and output are in different file formats that can be connected to excel software; the problem code file is easy to set up and modify and verify the model. Inputs are individual files, so it is easy to change them according to different scenarios.

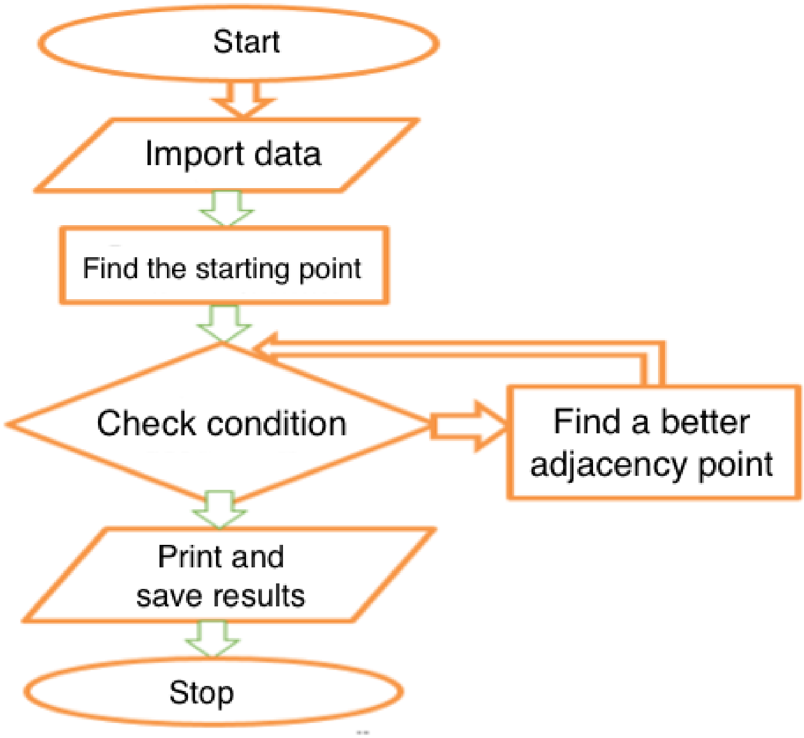

Figure 1. The optimal algorithm for GAMS software

3. RESULTS AND DISCUSSION

3.1. Assumptions in Optimal model

(i) The rice cultivation area can be reduced but not less than 60% of the total cultivated area to ensure food security, in line with the local master planning strategy.

(ii) Increasing the size for growing sweet potatoes and potatoes is possible. Still, the space for growing sweet potatoes is at most 3 hectares, and potatoes are not exceeded 2.5 hectares (depending on the land that can be planted with potatoes, these crops demand less water).

(iii) Reduce the area for growing vegetables and corn; the total area is less than 21.0 ha, the vegetable growing area is less than 8%, and the size of corn is less than 6%. (These crops need regular watering and high water requirements)

(iv) The area for planting elephant grass is not more than 3.0 hectares, just enough to meet the locality's needs.

Planting more cash crops such as peanuts and soybeans, the total area is at most 50.0 ha. The area under peanut cultivation is at most 10.0 hectares, and the place for growing beans is at least 8.0 hectares. According to the statistical yearbook of Hung Yen province in 2018, the yield of peanuts reached 3.49 tons/ha, and beans yielded 2.14 tons/ha. The net income of peanuts is about 21.0 million VND per ha and of soybean about 14.0 million VND per ha.

(v) According to the calculation, the total amount of water pumped from the system of irrigation works (the pumping station for agricultural irrigation in the whole commune is 600,000 m^3). The constraint represents a future water supply decrease in agricultural production with a scenario that only meets 75% o According to TCVN 8641:2011 Irrigation works for irrigation of food crops, the standard amount of water for irrigation of crops is as follows:

Table 2: Standard amount of water for each crop

No	Crop type	Standard amount of water (m^3/ha)
1	Rice	6000
2	Sweet potato	1200
3	Potato	1200
4	Vegetable	2000
5	Corn	2000
6	Elephant grass	1500
7	Peanut	2000
8	Soybean	2000

Constraints in the climate change scenario are shown in the ability to supply water for agricultural production; this scenario is only hypothetical; for the research problem, it is assumed to account for 75% of the total current water volume Supply, which means that the store is reduced by 25%.

After writing the code to solve the problem, the result of the problem will be the following table:

Table 3. Comparison of model results with current land use situation

No	Plant type	Area before optimization (ha)	Area after optimization (ha)	Up and down
1	Rice	120.0	71.5	-48.5
2	Sweet potato	2.0	3.0	1.0
3	Potato	1.0	4.5	3.5
4	Vegetable	15.9	12.0	-3.9
5	Corn	10.0	9.0	-1.0
6	Elephant grass	1.1	3.0	1.9

7	Peanut	0.0	10.0	10.0
8	Soybean	0.0	37.0	37.0

Thus, in terms of the area size of the results, the problem has been shifted in a positive direction to meet both the optimal economic efficiency and the efficiency of the water resource use market, in line with the set objectives of bringing social efficiency, contributing to improving people's living standards.

According to the results of the problem, the income level is higher than the current income level of 571.89 million VND, and at the same time, the amount of saved water for irrigation is 227 10^3 m^3. That significantly improves farmers' material life, contributes to society's construction and development, and uses water.

4. Conclusion

Systematized theoretical bases on optimization, land use planning, crop restructuring towards increasing the benefits of arable land, and the effects of climate change on agricultural cultivation through water depletion.

Build a general problem, model the optimization problem of crop structure conversion so that it can be applied to each locality and region, and develop and expand the optimization problem later.

Research and write optimization problem code on GAMS software to make solving optimization problems simple and flexible, and can quickly build different problem scenarios depending on the requirements of the problem maths

Applying the GAMS optimization problem solution model to solve the problem of land use conversion planning for agricultural land in Hai Trieu commune, Tien Lu district, Hung Yen province, through the results, the optimization problem is shown. Solved with optimal results and better optimal value than the current farming situation. This can be considered a basis for the commune to give directions for production in the coming time to increase the value of agricultural land use.

However, further research needs to include and study the conversion of annual and perennial crops (considering the long-term factor) to have a comprehensive approach to land use planning better and more complete.

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