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Geometric Modeling of a Mobile Vegetable-Growing Settlement's Land Plots

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Abstract

The article involves the development of a mobile vegetable-growing settlement's conception, designed to comprehensively address a range of economic, social and environmental issues. The article relates to sustainable agricultural development. It is to address the issues of creating an adaptable environment in agricultural fields for the effective use of precision agriculture in crop production. The aim of the paper is to develop the concept of a mobile vegetable-growing settlement, designed to make more efficient use of the precision farming systems in a new context by creating an adaptable agricultural field's environment. The concept was developed using geometric modeling based on a systems analysis of the situation. The result is a mobile and scalable land lot allocation system. Such a field distribution system creates an adaptable environment for more efficient use of precision agriculture systems, in both formats: traditional and modern crop production.

Keywords

Geometric modeling, Conceptual design, Precision agriculture, Land plots, Mobile settlement.

Introduction

The Sustainable Development Goals adopted by the UN are interrelated and aimed at addressing contemporary globally relevant problems, consisting of three components: economic, social and environmental. The proposed concept is aimed at solving problems related to the SDG-2 "End hunger, achieve food security and improved nutrition and promote sustainable agriculture". To address this issue, modern technologies such as precision agriculture are being applied (Cassman, K. G. et al., 2003). Current precision farming systems are now successfully implemented in soil and plant monitoring, irrigation and fertilizer management. Are these systems sufficiently used today? Yes, if it be considered that precision farming systems are mainly adapted in modern organized agricultural fields such as greenhouse farms, especially in developed countries. However, in unorganized agricultural fields in rural areas, especially in developing countries, these

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systems are not yet sufficiently implemented (FAO, 2021). Firstly, these are wide areas, for which some parameters of the currently existing precision farming systems are not adequate. Secondly, it is not expedient to turn these fields into greenhouse farms, as they produce more environmentally friendly products and have less impact on the environment (Hazell, P. B. R., et al., 2010). Consequently, it is necessary to develop an agricultural field structure in which the possibilities of natural farming can be maximally preserved and agro engineering systems can be developed to enable the full implementation of precision agriculture. It should also be taken into account that the majority of the population of developing countries is engaged in agriculture and in the future the bulk of agricultural products will be produced in these countries (Law of the Republic of Uzbekistan., 2024). The proposed concept involves developing an agricultural field structure consisting of a discrete fencing system, allowing for mobile flexible field division across a wide range of areas and cultivation times. The posts and panels of the discrete fencing system are uniform in size and feature construction elements that can be quickly disassembled and assembled, allowing for mobile field divisions, both in width and length. This fencing system, as an agro engineering system, can serve also as a discrete element of a precision farming system. The adaptable environment of an agricultural field is a discrete system that allows the real and virtual distribution of fields into plots according to various criteria of crop production. The discrete distribution system is based on the determination of discrete positioning points in the designed field using a square grid.

Methodology

To solve the problem the combined method consists of the following: system approach, conceptual design and geometric modeling. These methods were chosen considering the problems related to such fields of science as: crop production, engineering geometry, regional and urban planning, precision agriculture, BIM modeling and industrial design. Therefore, to solve the problem it needed to analyze a large amount of information on the state of the problem. The necessary materials related to this problem to confirm the conception idea. This process required applying the system approach method, because the concept is related to several interrelated issues of social, economic and environmental nature at the same time. Determining and connecting social, economic and environmental aspects of the problem by using a system approach showed the need to develop not simple design of the greenhouse or open air vegetable-growing field, but the conception of modern vegetable-growing settlement. This conception takes into account many conditions of contemporary issues of precision agriculture. In this case, a conceptual design method, as the task involves the realization of a completely new conception. The conception required carry-out a structure of the settlement, its constructive elements, and functional possibilities. Various land use systems, the system for providing vegetable produce to the population, and the system for creating new jobs were analyzed. Key relationships were identified, including the need to implement intensive vegetable growing technologies and services, employment, land use efficiency, and addressing environmental issues in the region. As a result of the systems analysis, design criteria were derived, including land use efficiency, employment, and environmental improvement. Design constraints include the geometric parameters of the land fields that meet the economic, social, and environmental needs of users. A model of the land field and its discrete cells was developed by selecting optimal geometric parameters. Geometric modeling was used as the modeling tool. AutoCAD software was used for the modeling. As it is known that the initial stage of the conceptual design process requires developing a model of investigating objects, mainly it can be a geometric model. Based on this means there was a geometric modeling method, which allowed developing a geometric model of the vegetable-growing settlement. In this case geometric modeling is the main method for solving the problem, as in the solution of the problem geometric parameters has a primary character. Basic structure of the settlement is its land plots system, which can be considered as one system. Other structural elements can be considered as sub system elements. Based on these conditions was developed a geometric model of the settlement's land plots system. This is justified that the developed model should ensure the application of the conception to different operating conditions for structural dimensions. The model had the character of scalability in dimensions. The model had different variants in order to choose the optimal for specific cases. Since the area parameters, as geometric, act as defining parameters, the solution to the problem is a geometric model of a vegetable-growing village. The developed model should ensure the applicability of the project to various operating conditions in terms of design dimensions.

Results and Discussion

The basic element of the structure of the modeled object is the land plots of a vegetable field. To identify the importance of land plots, it can be defining the types of agriculture by specialization as the starting point of modeling: grain, technical, fodder, horticulture and vegetable growing. Based on the task, it can be highlight the features of vegetable growing: It is conducted on relatively small land areas; it requires more labor; its vegetative period is characterized by its shortness and frequency. These features are prerequisites for the development of the model. To develop a model, it can be considered the relationship of the parameters of land plots with other parameters (Table 1). These data are based on the conditions of Uzbekistan (Juraev, T., 2024).

Table 1. Basic parameters of land users

Parameters	Gardeners	Peasants	Farmers	Agro holdings
Legal status	Individual, personal subsidiary household	Physical person with a plot from the state	Legal entity (Farm)	Legal entity (LLC, JSC, etc.)
Plot size (average)	0.02–0.15 ha	0.1–0.35 ha	5-100 ha	1000+ ha
Purpose of use	Family self-sufficiency	Family products + partial sale	Commercial production	Large-scale production
Type of land use	Personal or lifelong ownership	Lifelong ownership or lease	Long-term lease from the state	Lease, sublease
The level of mechanization	Minimal or manual	Low	Medium	High (GPS, equipment, drones)
Form of work	Family work	Family work	Family + hired workers	hired workers

After analyzing the relationship of the parameters of land plots with other parameters in this table, it can be determined the basic requirements for the model being developed. The proposed model should provide additional capabilities to available capabilities (Table 2).

Table 2. The possibilities of the proposed vegetable-growing settlement

Parameters	Available features	Additional features
Legal status	Small business by individuals	Large business by legal entities
Purpose of use	Cultivation for own needs of	Commercial cultivation
Land use type	Lifetime ownership	Lease
Mechanization	Low	High
Form of work	Family	Wage

Divisibility is ensured by applying a square grid to the vegetable field (Juraev, T., at al., 2024). This grid is optimal in shape for dividing the field into the necessary land plots. The size of the square, as the cells of the vegetable field and the plot, is 5x5 $=25m^2$. Here, the value 5 is selected from the values of the width of sowing and processing from 3 to 6 m, and is a multiple of the values of the plot sizes in any variants. The cell is the step of dividing the field and the smallest land plot. According to the tables' data analysis, the sizes of plots for vegetable growing ranges are from 100 m^2 to 50.000 m^2 (Table 3).

Table 3. Categories of land plots by area size

№	Type of categories	Type of use	Type of target group	Land plot's size ranges		Land plot's optimal sizes	
				m^2	ha	Shape, m	Area, m^2
1.	A-Micro	Special use	Service	0×10^2	0-0,01	0 10×10	5×10^1
2.	B-Small	Social use	Family	1×10^2-1×10^3	0,01-0,1	10×10 25×40	5×10^2
3.	C-Medium	Rental use	Family+ Business	1×10^3-1×10^4	0,1-1,0	25×40 100×100	5×10^3
4.	D-Large	Cluster use	Business	1×10^4-1×10^5	1,0-10,0	100×100 250×400	5×10^4
5.	E-Macro	Settlement use	Government	1×10^5-above	10,0-above	250×400 above	5×10^5

It can be selecting the categories of land plots from the data in the table: A) Special purpose cells that provide services, such as a seed laboratory; B) Social purpose plots to support the lower incoming families; C) Rental lots to run a family business; D) Vegetable clusters for entrepreneurs; E) Vegetable settlement for government politics. The table shows the range and optimal sizes of land plots. Developed geometric models give possibility to: Land plots' dividing system for any required business and social variants by taking into account agricultural and economic conditions (Figure 1); Land plots' shapes, recommended for optimal using in agricultural operation processes (Figure 2); Land plots' discrete fencing system to mobility dividing for land users by area size and vegetative usage seasons (Figure 3).

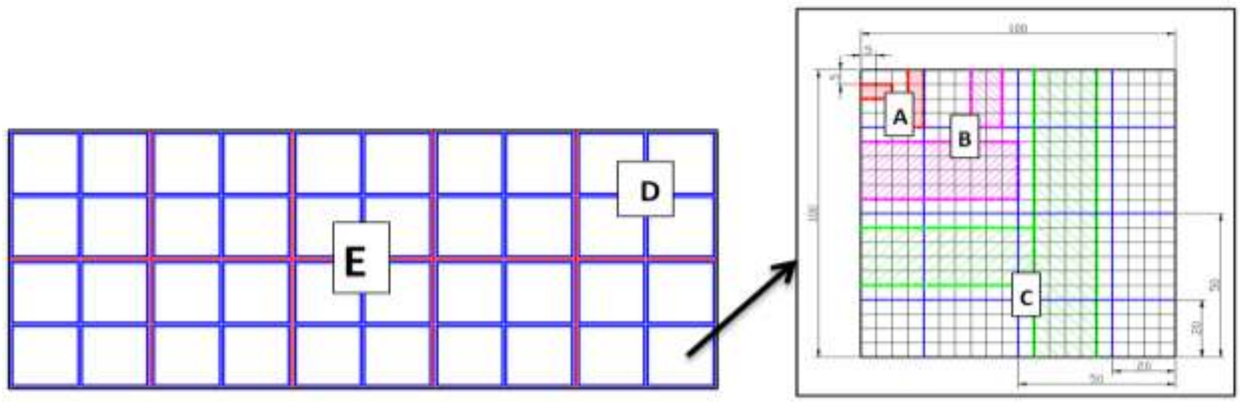

Figure 1. Land plots' system structural model

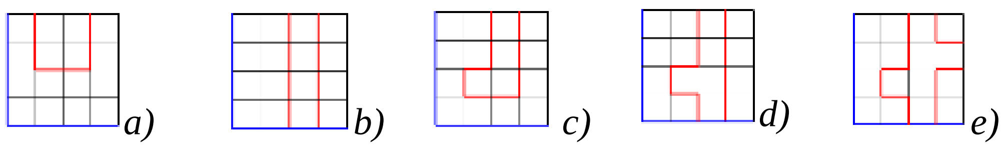

Figure 2. Land plots' shape variants:
a) square, b) rectangle, c) ***l****-shaped, d)* ***1****-side branch, e)* ***2****-side branch*

Figure 3. Land plots' discrete fencing system and its dividing variants

Changing the plots' width is accomplished by adding cells from or to adjacent plots. Changing the plots' length is accomplished by subtracting or adding cells to the rental fields. Unlike existing land consolidation and farm planning methods, the proposed model is primarily targeted at small-scale land users, i.e., gardeners, peasants and farmers. This is because, in Uzbekistan, vegetable growing is conducted on small farms and requires a larger labor force. The implementation of such a discrete fencing system requires public acceptance in terms of transition to a new, mobile land use system. This system has an initial limitation related to the cost of the project, which requires expenditures on its implementation. The "mobility" aspect is explained by the system's sustainability over time, which is ensured by the ability to distribute and redistribute land plots between commercial and private users, and by providing social support for the latter.

Conclusion

The proposed conception, as an innovation solution, opens up new possibilities for digitalization and intelligent farming. Hence, new modern jobs in rural areas are organized, sustainable agriculture is ensured, and the efficiency of land use in agriculture is increased. The conception of the mobile vegetable-growing settlement provides a comprehensive solution to three components: Economic problem, e.g. increasing productivity; Social problems, e.g. creating new jobs;

Environmental problems, e.g. reducing environmental impact. The conception can be implemented in developed and developing countries. The proposed concept, as an innovative solution, opens up new opportunities for digitalization and intelligent farming. Thus, new modern jobs are created in rural areas, sustainable agricultural development is ensured and the efficiency of land use in agriculture is increased.

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