Automation Prospects in Rice Growing

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Abstract. This article considers the solution for the automation problem in rice growing. Currently, every seventh resident of the earth is involved in rice growing and processing, and all countries experience insufficiency of labor resources for this work. To solve this problem, the authors suggest using an automated agricultural self-propelled platform (AASPP) that will help completely automate rice growing and solve environmental, economic, social, and infrastructural problems of rural residents. Besides, it can help eliminate many of the technical problems of rice growing, such as the horizontal leveling off the field, corrosion of agricultural machines, complying with agrotechnical standards when planting, and the correlations between the terms of agrotechnological works using machines and mechanisms and soil humidity and other natural conditions. Solving the problem of rice growing automation will help satisfy the needs of this agricultural sector in labor and free 30-50% of people involved in rice growing to be employed in other economic sectors.

1. Introduction

Today, the population of the Earth exceeds 7.9 billion people (Figure 1) and it is aging rapidly except for Africa. Many economic sectors experience a lack of skilled and low-skilled labor force, but the situation is especially difficult in agriculture.

![Figure 1. The demographic forecast of global population growth [1].](image-url)
If agricultural production drops, many countries will face famine and social disturbances, yet some countries have problems with food supply even today (Figure 2). Surprisingly enough, countries that experience famine have perfect climate conditions, and their agriculture should be thriving.

Rice is the most valuable crop because it has the highest proportion of calories per hectare of cultivated land. The global production of rice equals 742 million tons a year (211 million tons in China, 158 million tons in India, and 1.08 million tons in Russia). In China, rice is the key food for 65% of the population, and the same is true for all of Asia. The consumption figures there range from 78 kg per person a year (China) to 170 kg per person a year (Laos). In Russia, it is 4-5 kg per person a year.

Today, over one billion people all over the world are employed in rice growing and processing. All of the countries that produce agricultural goods have typical problems like the lack of workforce and the increase in its costs, the reduction of cultivated lands, the increase in land rent, land degradation, low mechanization, and lack of automated processes, as well as a great deal of social and economic problems: in China [3], India [4], Malaysia [5], Nepal [6], and Russia [7].

The primary problems that should be solved by the automation of agriculture in general and rice growing specifically are the problems of the workforce and technical problems.

Workforce problems in agriculture include the following:
- the accelerated social differentiation into the rich and the poor working in the agricultural sector;
- low wages;
- the increasing gap in the quality of life and comfort between urban and rural areas (this causes young people and skilled workers to migrate to cities);
- horrible working conditions, especially in rice growing;
- inefficient use of the workforce, frequent downtimes (due to weather, seasons, etc);
- low availability of social and cultural infrastructure.

The technological problems of rice growing include the following:
- manual labor automation;
- planting accuracy;
- providing the carrying capability of the soil for mechanism movement;
- maintaining the field surface horizon within the accuracy of ± 1.5 cm;
- machine and mechanism corrosion;
- monitoring soil fertilization, weed and insect infestations, and the overall state of the cultivated plants;
- eco-friendliness of crop farming.
These problems are completely or partially solved by the introduction of an overhead self-propelled platform as the basic crop farming machine that moves on concrete supports (in rice growing).

2. Materials and Method. Overhead systems as a promising technology for the automation of agriculture

The idea of the overhead agricultural system first emerged in the early 20th century and found limited use in vegetable watering and harvesting systems. It resulted in the reduction of the negative impact on the soil and energy consumption, and the productivity of labor increased [8].

Overhead systems feature a truss or beam design with a large span where agrotechnological mechanisms and farming devices are installed. This structure is driven by a pneumatic system or it can move along a railway. The most typical overhead agricultural system is the automated overhead agricultural complex (AOAC) [9].

The AOAC system comprises a railway and a gantry with attachments moving on it without soil compacting. When the AOAC is controlled by a computer, it is possible to provide the prompt and accurate performance of technical operations for each of the plants, which will help obtain good harvests, preserve the fertility of the land, and solve the environmental problems associated with crop farming by localized and accurately dosed application of fertilizers, herbicides, and poisons.

The drawbacks of the AOAC unit include its high metal intensity (17.5 t/ha) as railways take up to 10% of the fields. Besides, in the units with large spans, the gantry can become warped when moving, which can result in reduced accuracy and accidents.

In a different overhead system, the gantry is moving on concrete piles, which complicated the equipment of the field (during the installation of piles, significant deviations a possible that are difficult to adjust) [10]. During the operation, the pile cap can arbitrarily move in the vertical or horizontal direction due to ground settlement or heaving, which will reduce the accuracy of technological operations and the movement safety of the overhead system.

The next overhead system, the overhead precision farming robot (OPFR) [11-13] moving in a permanent gravel rut, cannot be used in rice growing due to the corrosion of the propelling mechanism due to the presence of water in the rice field.

3. Results

The best overhead system for rice growing is the automated agrotechnical self-propelled platform (AASPP), [14-17].

Figure 2 shows the general layout of the AASPP platform.

Figure 3. Overall layout of the AASPP.
1- gravel bed; 2- concrete blocks; 3- lengthwise movement girders; 4- cross-movement girders; 5- platform; 6- attachments; 7- crossover support beams; 8- electric jacks; 9- lengthwise movement girder traveling gear (3).
The solutions used in the AASPP design improve the known overhead agrotechnical systems. Instead of chain tracks, wheels, pneumatic tracks, railways, cable drivers, and pile piers, the AASPP uses concrete block supports (2) that are laid on the gravel bed, whose thickness is used to adjust the operating (upper) horizon of the block (1) within the horizontal accuracy of ± 5 mm. Platform (5) is moving along the grounds on concrete blocks using extending beams (3) that operate incrementally. The platform carries attachments (6) that perform agricultural operations automatically. The attachment module can move along the crossover frame girders (7) made of the U-shaped channel that serve as guide rails. The platform is equipped with a satellite navigation system for orientation with an accuracy of up to ± 10 mm or a local radio signal orientation system with the accuracy of at least ± 10 mm.

The AASPP moves using electric motors powered by solar panels and accumulators. A gas-powered electricity generator is used as an emergency power source.

Since the platform moves on solid concrete blocks, it does not depend on soil humidity (bogginess), and the power consumption required to move the unit across the field reduces (the platform is moving in a perfectly horizontal plane without dips or humps). Thus, agricultural practices become independent of the soil and climate conditions affecting the mechanism movement. The precise rationing of fertilizers and herbicides for every plant, as well as the reduced soil cover destruction, provide for the increased environmental friendliness of farming. The precise orientation of the platform during planting allows for the automated keeping of a registry of all plants. The precise orientation of process equipment against the cultivated field and plants as well as the automated control system provide the precision of all agricultural works. The size of the platform is selected taking into account the following: the span size of the overhead structure should be optimized against its weight, platform maneuverability should depend on the typical size of a single field and the overall amount of cultivated on a farm, the authors suggest using 10x10 meter fields. This size would fit both small farms and large agricultural companies.

The platform is made of slender U-shaped sections housing retractable propelling beams that are 10 m long and rectangular in cross-section. These are driven by the jacks (8) and the lengthwise movement girder traveling gear (9). When the lengthwise movement girders (3) are extended, the platform is propelled along the field, while processing it. When the platform needs to be relocated to a new field, it moves across the main processing path on extensible air casters with built-in electric motors. The movement pattern for a basic platform is shown in Figure 4. Position I is the initial one.

Position I is the initial one. To move the platform in position II, the frame is lifted by the jacks (D) stationed on concrete blocks (2). The lengthwise movement girders (3) are unloaded and, using the traveling gear, the beams are extended, and the platform shifts into position III. Jacks (D) go down, and lengthwise movement girders lie on concrete blocks (2) in position IV. The platform lies on the lengthwise movement girders. By putting the traveling gear of the lengthwise movement girders in reverse, the platforms shifts into position V. At the same time, attachments (5) perform the required operations, after which the cycle is repeated (I-V).

During the platform movement, it is crucial to maintain the position of the gravity center of the platform within the perimeter formed by the jacks. Otherwise, the platform may collapse when movement girders are extended. This is achieved by the fixed position of power-supply equipment (batteries, solar panels, emergency generator) on the platform.

Another advantage of the automated agrotechnical self-propelled platform is that it can combine the technological operations (soil loosening, horizontal field leveling, soil fertilization express analysis, applying the missing fertilizer components, seedling planting) in just one pass of the machine across the waterlogged field, with agricultural processes synchronizes over time.
4. Conclusion
The automated agrotechnical self-propelled platform (AASPP) helps reduce the dependency of farming on weather conditions and bogginess (in rice fields), improve the quality of land preparation works (especially the horizontal leveling of fields) for the sowing of rice, plant handling, and harvesting, and reduce the power consumption for movement through complete automation of agricultural processes.

Platform movement and the performance of operations by attachments are separated in time, which improves the precision of required agricultural operations. The mechanism can work all day long automatically. At the same time, it ensures high environmental friendliness and reduces the destruction of soil by the mechanisms, and facilitates the addressed and standardized application of fertilizers and chemical plant protectors. Compared to other overhead systems, this one significantly reduces the required time and material inputs for field equipment.

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