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The Need for Creation of High-tech Tractors of 0.6-2 Traction Classes with High Degree of Automation

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The Need for Creation of High-tech Tractors of 0.6-2 Traction Classes with High Degree of Automation

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Abstract. The article shows the need for the creation of tractors of 0.6-2 traction classes (nominal traction force 5.4-27 kN) with a high degree of automation, which are in demand in the agricultural industry. The authors present the principle of creation of the 4WD modular platform with hybrid powertrain and unification of axles and some technical characteristics for each traction class. It is indicated that for the conditions of digital agriculture it is necessary to provide the possibility to control high-tech tractors in remote and/or unmanned operation modes.

1. Introduction

The main tendencies of development of modern agricultural vehicles are: improvement of operational characteristics (increase of productivity, power, speed, pressure in the hydraulic system; transition to alternative sources of energy; decrease of pressure on the soil; improvement of working conditions of the operator); implementation of automated and remote and/or driverless control, telemetry systems; transition to electric and hybrid drives; development of new vehicles on the basis of modular platforms; reduction of the labour intensity of technological operations; transition to digital agriculture with development of precision farming technologies. Furthermore, agricultural producers are faced with the need to improve the efficiency of the use of machines and farmland, reducing the production costs, and optimizing technological operations during the work.

In connection with the above-stated, the aim of the research is to create high-tech tractors with automated control systems equipped with modern information systems. Development of such tractors will allow engaging modern technologies, digitalize the industry, involve new personnel to direct or remote work in the agricultural industry, including younger people actively exploring information technologies.

2. Problem setting

On the basis of the analysis of tendencies and the forecasted situation in agriculture of Russia to show the necessity of development of high-tech tractors of 0.6-2 traction classes with a high degree of automation.



3. Results

The analysis of the current and forecasted situation in agriculture in Russia shows the following trends (Figures 1-3): there is a steady reduction in the number of employable population in rural areas; it is planned to put into operation unused lands for agricultural production; an increase in the fleet of tractors for agricultural works is forecasted.

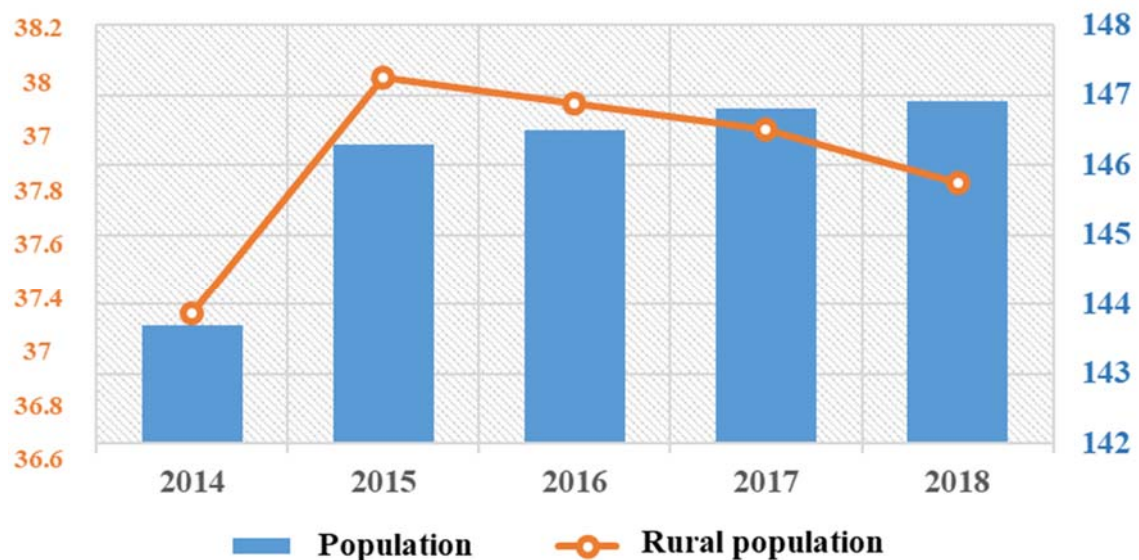
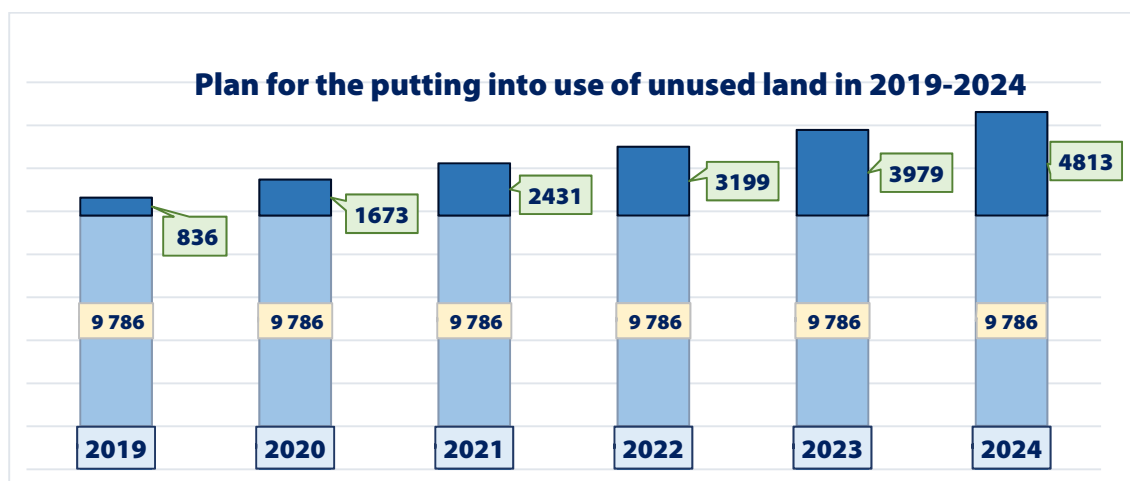


Figure 1. Population change in Russia (million people).



Area of arable land as of 01.01.2019, thousand hectares
Dynamics of arable land putting into rotation in 2019-2024, thousand hectares

Figure 2. Plan for putting into use of unused land.

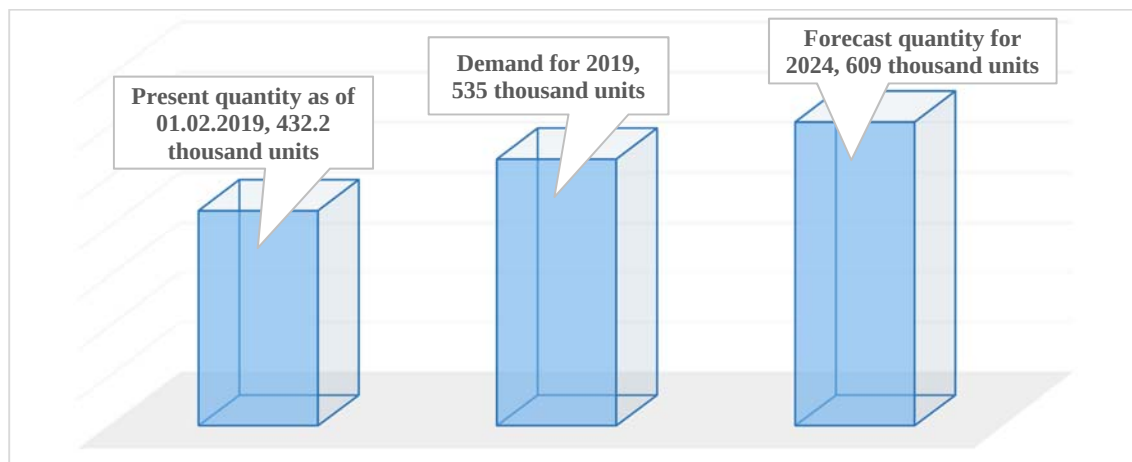


Figure 3. Current and forecasted quantity of tractors.

Tractors of traction classes 0.6-2 can be used in various agricultural operations.

Traction class 0.6 (nominal traction force 5.4-8.1 kN). Tractors of this class are used directly in agriculture and involved in various technological processes: preparation of soil for sowing, sowing; planting of vegetables and roots; planting of decorative and fruit-bearing trees and bushes; care of sowing, care of bushes and trees; harvesting; preparation of feed for animal husbandry; transport, municipal works, drive for various stationary units.

Traction class 0.9 (nominal traction force 8.1-12.6 kN). The range of possible works in this class is slightly wider. Both 2WD and 4WD tractors are presented, and models with low ground clearance for work in mountain areas are developed. It becomes reasonable to install gearboxes with a wide range of gears. The main application of this class is: ploughing light soils; pre-sowing preparation of the soil; interrow hilling; pest control (crop spraying); harvesting; haymaking; transport work.

Traction class 1.4 (nominal traction force 12.6-18 kN). Tractors of this class are designed for operation in difficult road conditions. They are the most effective at performance of works performed by tractors of traction classes 0.6 and 0.9 and, taking into account their exceptional properties, it became possible to use such vehicles for ploughing of light and medium soils, cultivation, harrowing, application of fertilizers in the soil.

Traction class 2.0. This class includes tractors with wheeled as well as caterpillar chassis. This is due to the power of the vehicles and the conditions in which they have to perform their tasks. This class includes garden tractors as well as general purpose and special purpose agricultural tractors and straddle tractors. In addition to the above-mentioned types of works, there are maintenance of vineyards, beet-growing and gardening works, work in mountainous areas.

Modern high-tech tractors of 0.6-2 traction classes have to be developed on the basis of the self-propelled modular platform with a hybrid powertrain, unified axles and variable wheelbase, depending on the traction class (Figure 4). Hybrid powertrain variants: ICE + generator + electric motor or ICE + generator + battery + electric motor. The axles of a modular platform with this type of powertrain have to be equipped with wheel motors. In order to increase manoeuvrability, the tractor has to have crab steering. All units, assemblies and systems of high-tech tractors have to have high reliability [1, 2], because the failure of any element of the vehicle can lead to the interruption of agricultural work.

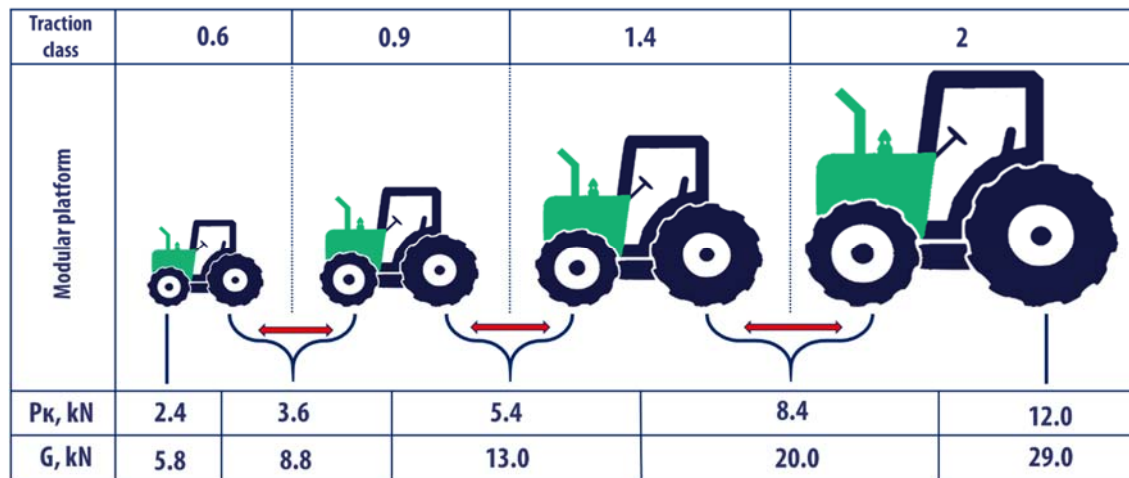


Figure 4. Principle of creation of a 4WD modular platform with a hybrid powertrain and axle unification.

Table 1 shows some required technical characteristics of high-tech tractors of each traction class with the 4WD modular platform.

Table 1. Target indicators for the development of the 4WD modular platform.

Indicator	Traction class			
	0.6	0.9	1.4	2
Engine power, kW	24	36	56	80
Completeness of power usage (reference power intensity), kW/kN	1.5	1.5	1.5	1.5
Number of technological spaces for equipment, spaces, not less than	3	3	3	3
Number of technological spaces for containers, spaces, not less than	2	2	2	2
Productivity of the technological process (ploughing), ha/hour	1	1.7	2.5	5
Cost of technological process execution (ploughing), RUB/ha	1106	989	850	843
Maximum wheel ground pressure, kPa	74	80	80	80
Row spacing (adjustment), mm	500	500	500	500
Maneuverability (turning radius), m	2,3	2,9	3,1	3,85
Agrotechnical clearance, mm	700	700	700	700
Transport speed, km/h	30	40	60	60
Load capacity of front linkage, kg	500	1000	1700	2800
Carrying capacity of the rear linkage, kg	1000	1700	2800	4000
Front PTO	+	+	+	+

Development of high-tech tractors of 0.6-2 traction classes for conditions of digital agriculture has to provide possibility of their control in remote and/or driverless operation modes and, accordingly, presence of reliable and safe system of autonomous motion, including at agrotechnical works, with

following functions: recognition of obstacles; automatic stop before an obstacle and/or its bypass. This includes the following:

- gradually introducing into mass production the functions of assisting the operator to stop before an obstacle, pull out of the row, etc., and make them informational at first. At the same time, the development of active assistants to the operator and driving machines for the mass sector has to be carried out (at present they are characterized by high cost and low level of implementation);
- making active operator assistants widely available. At the same time, to work out the possibility of mass implementation of driverless systems;
- determining the necessary and sufficient set of sensors for the computer vision system, considering, the task of minimizing the cost of the object;
- determining the necessary technical equipment of the basic chassis, their level of electrification, control, the possibility of system operating in the tractor's information network.

In addition, it is necessary to develop: a vector map of a field with indication of static obstacles (poles, etc.); the movement of the tractor along the route formed in the field; the detection of obstacles on the route of the tractor using the duplication of sensors of computer vision to improve the reliability of the identification of obstacles; stop or bypass of an obstacle; informing the dispatcher about the presence of obstacles in the lane of the tractor; online transmitting telematic data to the dispatcher's room; interaction of several tractors to work in the same field at the same time.

There is a large number of researches in the field of driverless control of both agricultural vehicles and automobiles [3, 4]. However, all known systems to date have not found mass application primarily because of the high cost of the element base in terms of one unit of equipment. In addition, when moving a high-tech tractor with a high degree of automation or tractor-implement combination, the accuracy of maintaining a given route will be affected by: the probability of different state of the supporting surface under each wheel (humidity, surface hardness), the performance of agricultural work at any time of day, the presence of various natural and atmospheric factors, increased dust content during agricultural operations, leading to contamination of sensors of computer vision sensors. All this has to be taken into account when creating a control system for high-tech tractors in remote and/or driverless operation.

Digital agriculture will allow efficient and flexible redirection of unused power by high-tech tractors of different traction classes (Figures 5, 6).



Figure 5. Power requirement for different types of technological operations.

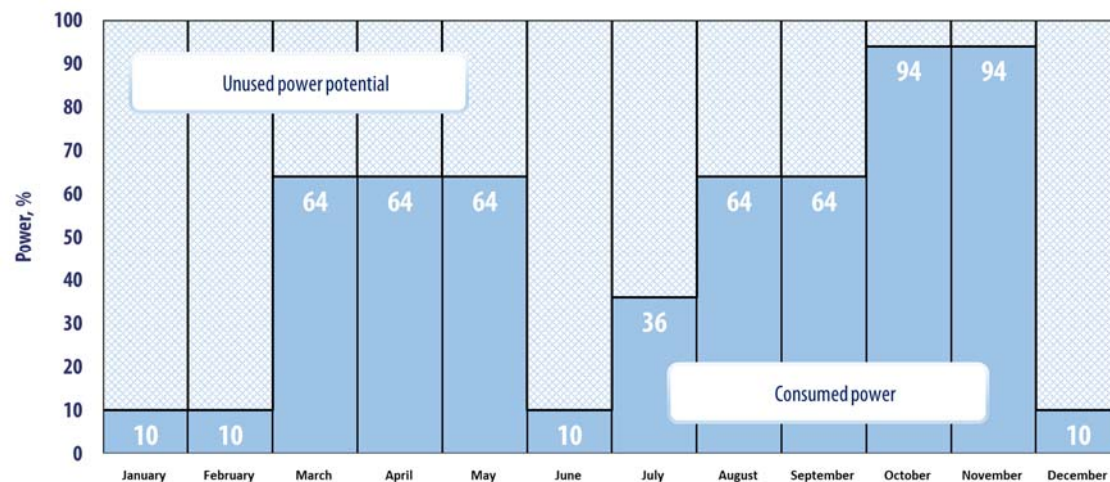


Figure 6. Annual balance of machine and tractor fleet power for the Southern Federal District in grain crop cultivation.

4. Conclusion

Development of high-tech tractors of 0.6-2 traction classes with a high degree of automation would enable reaching the target indicators of the project “Digital Agriculture” - ensuring the digital transformation of agriculture through the implementation of digital technologies and platform solutions for technological breakthroughs in the agro-industrial complex and achieving doubling productivity growth at “digital” agricultural enterprises, as well as another project “Technical modernization of the agro-industrial complex” - providing in 2025, with the state support, renewal of tractors in agricultural organizations to the level of 3.4% [5-10]. Development and use of high-tech tractors of 0.6-2 traction classes with the autonomous control system on the advanced component base with electromechanical and hybrid drive will allow raising essentially efficiency of agriculture and make the transition to its digitalization.

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