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Ecological Balance of Technogenic Processes and Tractors of Fifth Generation

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ABSTRACT

Increasing unit capacities, in particular, of the wheel-mounted tractors upto 450–500 h.p. leads to a sharp increase in mass and hence to the excessive soil over compaction and reduction of yield along the tractor wheel track by upto 30%. The slipping of wheeled running gears up to 12–15% is noted, which results in actual rotary tillage of soil surface and the deterioration of particle size distribution of a production layer, and causes wind erosion. As compared to the track-type vehicles, the wheeled vehicles have a significantly higher design mass. Using tractors of classical design aggravates the maneuverability of a machine-tractor aggregate (MTA), and increases the width of a headland. A stepped track drive of a tractor doesn't contribute to the continuous full use of the installed capacity of an internal combustion engine (ICE). At present, the ecological balance of the technogenic processes in agrocenoses is provided by using the mobile power units of the fifth generation, the technical structure of which is based on the formation of multiprocess small-run MTA. According to preliminary calculations, the power units of the fifth generation reduce the number of technological operations by 40% as compared to the product complexes of vehicles based on the use of tractors of the fourth generation. Studies show that the ecological balance of the technogenic processes in the modern structural and technological schemes of tractors can be provided only if using the tracked vehicles of the fifth generation.

Keywords: Technogenic processes, slipping, ecological balance, mobile power unit of the fifth generation, ground pressure, agroeco systems.

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INTRODUCTION

The ecological balance of the machine-technological processes (MTP) in the agricultural product agroecosystems is becoming an urgent requirement of the modern agribusiness. The gradual decline in natural soil fertility, the intensive reduction and aging of MTP resulting in the majority of agricultural enterprises in the reduction of the efficiency of machine technologies; the soil overcompactionwith the wheeled systems of tractors and combined harvesters of ever-growing masses; the deterioration of the structure of topsoil with a significant reduction in the use of traditional in Russia organic fertilizers; the steadily sprawling wind erosion carrying away the huge masses of fertile soil and aimed, as it is already clear, at the desertification of arable arrays — all these are the negative signs of interaction between the productive facilities, a man, and the production layers of soil in the agroecosystems. Unfortunately, the results of many of these destructive processes are not seen immediately; it takes decades to see even the negative manifestations and understand some, so to speak, transient processes. Specialists in agroecology, however, clearly see all of these phenomena "with the naked eye"; hence, there is their insistence on the ecological balance of technogenic processes, primarily in agriculture.

Today, we are no longer able to cut out of the furrow slice of soil a cubic meter of chernozem, as did our ancestors over 100 years ago, what impressed the whole world: except for Russia, such furrow slice can be found nowhere else. It is an integral index; it says it a lot about the land use or even all.

Thus, the issue of the **ecological balance of technogenic impact** is the matter of food independence of Russia in the near future, and in view of the socio-political situation that is emerging around our country (certainly a "return to basics" [1]) it is an issue of survival for us.

In our consideration for a few more concrete definition, we narrowed this issue to the level of using mobile power units as the machinery of wide purpose and as the machinery, which is much more loaded in technological processes in comparison with the operating machines of special purpose (grain, fodder harvesters and other similar means of mechanization).

Aim of the study:

To develop a machine-engineering support for the processes of crop production in agri business as the balanced technogenic interaction with the production agroeco systems in agrocenoses.

Objectives of the study:

- To identify and systematize the direction of the negative technogenic effects in agroecosystems.
- To suggest real machine technologies and technical facilities that can be applied as the basis of balanced interaction in the agrocenoses.
- To substantiate the efficiency of the basic means of mechanization under conditions of the balanced interaction in the agroecosystems using an economic-mathematical model of technological complexes.

The methodology for solving these tasks: Based on the extensive observations and analysis of the technological processes of crop production, the study of the interaction of technical means with the production agro-ecosystems and of the dynamics of technogenic processes, the development and use of the economic and mathematical models for evaluating the comparative effectiveness of the traditional complexes of vehicles with innovative technologies and technical means of the fifth generation as the basis for the ecologically balanced functioning thereof in agrocenoses.

Study results: As the productivity grows, the design masses of technical means increase (of course with an unchanged technology). Thus, while in the middle of the twentieth century the most complex vehicle — a combined harvester — had a mass of 7–8 tons (for example, a grain harvester SK-4), by the end of this century the mass of a combined harvester has increased almost 2 times (a combined harvester "Don-1500").

The change in the weight of wheeled tractors was even more impressive.

While in the same period a widespread wheeled tractor, MTZ "Belarus", had a mass of 3.5–4.0 tons, in the second half of the 20thcentury a vehicle "Kirovets" of model K-700/701 was produced as the main tillage power vehicle with the weight of 11–13 tons. The further (contemporary) modernization of these machines as a family of K-744 (P1; P2; P3) has increased the mass up to 18 tons. The ecological imbalance in the interaction between these machines in the form of increased soil compaction, often above the level of acceptance, lies actually on the surface. During sowing maize using the complex of row-crop planters and a tractor K-701,one of the authors observed a deep, up to 15 cm, track from the wheeled tractor propulsion unit, into which a seed grain dropped successfully becoming a catch for birds (adapted to the treated seeds); the swarms of the latter, as a rule, accompany any planting MTA.

Numerous studies, primarily in the All-Russian Research Institute of Agricultural Mechanization (VIM), have proved that wheeled propulsion units of heavy tractors compact soil essentially: the value of the specific ground pressure makes 1.4 kg/cm^2 or more. It is found out that the yield of grain crops on the track is reduced on average by 30% [2-4]. Bearing in mind that the coverage of an eight-body mounted plow — a traditionally "regular" toolforaK-701 type tractor— makes 280 cm, and the total width of the track for two wheels is 140 cm, we obtain a decline in crop capacity at already 50% of the area treated by tractor. However, even this is much more than that. The heavy wheeled vehicles not only over compact the arable horizon reducing its production properties, but also affect the underlying layers to a depth of 100 cm producing a certain compaction by the moving mass, and thereby interrupting the movement of subsoil moisture to the overlying layers, which are the only ones that provide moisture to plants in drought conditions. As a result, the droughts have sharply become more frequent.

The third most important factor of the ecological imbalance is the impact of the wheeled propulsion unit on the surface layer of soil in the form of slipping. As shown by the numerous experimental studies, including the data from the machine testing stations (MTS), the work slipping value of a wheeled propulsion unit of a heavy tractor reaches 12—15%.**Firstly**, it leads to the destruction through rubbing of the natural soil aggregates contributing to a significant dust formation and "feeding" wind erosion with this dust; the soil loses a highly significant part of the fertile fraction. **Secondly**, the slippage results in a considerable fuel burnout. It is easy to calculate the amount of energy loss due to slippage, which is estimated to equal to 50–60 h.p.

The makers of heavy wheeled tractors quite often recommend installing two more wheels on each of the two axles to reduce specific ground pressure. Thus, we get an eight-wheeled rotary tiller. If the actual width of an eight-wheeled vehicle is 4.5m,such aggregate must be equipped with a fourteen-body plow (naturally, of a pull type). At the same time, the minimum drawbar capacity will be 9,000 kgf. It is easy to calculate that the weight of such a tractor must be within 22 tons, and the power of the engine at a speed of 10 km/h should be at least 400 h. p. Already according to the given preliminary parameters, it is suspected that the village hardly needs such a wheeled tractor (or rather — does not need at all). However, in Russia there already are these and even bigger tractors: these are the vehicles from the family Versatile; one of our entrepreneurs purchased a plant for the production of tractors.

Moreover, the last significant property of heavy wheeled power vehicles is that in order to use the full force of traction, it is needed to form on their basis the loops of technological machines; the latter, in a single MTA (all working machines should have the same —similar—agroterm for execution of technological operations), form extremely long aggregates. They require a broad headland, a complex trajectory of turning at medium working speeds, which ultimately reduces the efficiency of MTA and, as a consequence — its productivity. If we add thereto a considerable machine set-up time, the difficulties in their application become clear.

Further, without considering the economic factor of industrialization [5], we will focus on the technical side of the problem. The fathers of the Russian (Soviet) MTA industrialization in the early thirties of the last century chose (or substantiated as they were highly educated people in the scientific and technical point of view) the direction consisting of two blocks: the development and broadest application of **track-type tractors** (after all, Russia is the birthplace of such tractors) as the mobile power units; the second block is the design and use of complex technological machines (primarily grain harvesters) as **trailing units for track-type tractors** in a non-motorized version, and then with the installation of independent ICE only for the drive of technological working bodies. The track-type machines so easily fitted into the system of agriculture and cultivation of field crops that other options of the drive for working bodies and machines were not considered:

having gone from the horse traction, the creators of progress could stop on wheeled tractors, especially as the latter already existed; but at that time, they, the creators, we suppose, saw and evaluated the advantages of a track-type propulsion unit over a wheeled one. At the same time, **the machine-building factories** had to **design** and build the track-type tractors, being quite powerful for that period, for their mass production "at sight".

The massive use of tracked tractors in the collective and state agricultural enterprises of domestic agriculture made it possible to increase the labor productivity especially in grain production, although the first generation of tractors in its technical **parameters**, especially in the manufacturing quality, left much to be desired. However, the second generation of tracked vehicles was significantly higher both in terms of manufacturing and technical solutions. Furthermore, a tracked tractor DT-54 of Class 3 with a power of 54 h.p. and a mass of approximately 6.5 tons put into mass production in the Altai Tractor Plant in 1949 was flawless. A heavy tractor S-80 of Class 5–6 with a power of 76 h.p. and a mass of 11 tons was of high quality. The machine worked with a hitch group of two trailed five-body plows and provided such a high economic effect that the grain farm "Gigant" in the Rostov Region (the SalskDistrict) having a large number of tracked tractors S-80 ensured the lowest cost price of grain.

Thus, the new mobile power engineering in agriculture in the form of tracked tractors has proven to be in harmony with the environment even as compared to the horse traction and hand sowing. While studying in detail the characteristics of the technological processes in the mass use of tracked tractors, in particular the landmark work of V.S. Fraer [6], it is possible to assert that if during the period of industrialization the mentioned fashionable ecological concepts had appeared, they would have not carried a fatal negative sense.

However, since the sixties, the authorities "from above" persistently introduced the idea of the feasibility and necessity of introducing into production the **wheeled tractors** instead of tracked ones, for the reason that it is done "both in America and around the world" (the great strategic argument of the domestic bureaucracy has survived to the present day). That was an ironic twist of fate, since just in the same period — the beginning of the sixties — the American farmers set their state in front of the challenge of switching to the so-called **Russian type organic farming system**, one of the problems of which was the **introduction of tracked tractors** into the agriculture [7].

The Americans solved **their** problem, and in the eighties and nineties, they started the mass production of tracked tractors and even exported them to Russia. We also solved **our** problem: at the beginning of the new century, we **stopped producing tracked tractors** at all. We did not manage to put into production the tracked tractor of Class 6 "Alttrak" T-250 developed at the end of the last century, which showed an impeccable result during testing; while now there is already no place for its production [8]. Just to the honor of the chief designer of the Kharkov Tractor Works (Ukraine) B.P. Kashuba, a tracked tractor of the fourth generation of Class 3 — T-150 was designed, which has been successfully working so far in our country (over 40 years!), and on the earth of its founders it turned into a "five ton vehicle" KhTZ-181 (Fig. 1). That's the way the tractor drama of the last 50 years looks.

Mainly technological, advantages of the tracked vehicles over the wheeled ones: they provide a higher coefficient of traction at the same trailing weight, have significantly less slippage of undercarriage, produce smaller ground pressure, do not exhibit a profound effect on the subsoil layers, and do not reduce crop capacity on a track since there is no track at all.

Fig 1: TractorKhTZ-181

Notwithstanding the provided fundamental advantages of track tractors as compared to the wheeled ones, the production of the latter was stopped, and only the holding "Agromash" starts renewing their production (we are talking about the tractors for agricultural purposes). However, the strategic direction of this deployment, as the analysis shows, consists in the resuscitation of the machines of the **fourth generation**, which in general have already been designed. We should also note that, if we had worked on the tracked tractors of mass production, then, firstly, Russia would have already had the mass production of such tractors of the **fifth generation**, which would have inevitably been associated with the more advanced technological processes, and secondly, the "socio-political" drawback of a tracked vehicle —the steel tracks, on which it is impossible to drive along the paved roads — would have been successfully overcome, for the rubber reinforced crawler tracks are already available commercially.

The fourth generation of tracked tractors (actually existing T-150, KhTZ-191, planned for production T-250 "Alttrak" under the brand name of A-600) provides certain material to address the issue of their improvement.

Firstly. Because the installed capacity of ICE is constantly increasing, there is a need to develop mechanisms that would ensure a constant (in any technological operations) maximum use of ICE power for a technological process. One of such mechanisms may be a **continuously variable hydraulic drive of undercarriage**. In addition, in the strategic plan of modernization, automatic devices can carry out the use of the maximum ICE power relatively easy [9].

Secondly. Currently, the heavy machinery, including both tracked and wheeled vehicles, is provided with the very complex and expensive gearboxes. A large number of gears that are made of expensive high quality metal are installed there in using the extremely high and expensive technologies. Furthermore, the accepted ability to switch gears (and not ranges) without interrupting the flow of power (achieved through the efforts and the requirements of a large number of scientists and farm machinery operators) is illusory: in order to switch to the gear n+1 from the gear n (or vice versa), it is required **to disable** the flow of power from the gear n using a hydro pressure coupling, and to direct energy flow to the driving pinion of the gear n+1, i.e., still **to break** the flow though without moving gears or spline couplings. The hydraulic drive performs this operation really without breaking the flow of power, and the starting air compressor in such a scheme **may be missing**.

Thirdly .With the growing power and towing capacity of tracked tractors, the overall performance of MTA increases. One of the most common structural and technological trends in the solution of this problem is furnishing a multi operational MTA via synthesis on the back (only!) mounted or trailed system of several tools (or machines), the work of which may be accepted simultaneously according to the agroterms (this was mentioned above).

Another less common option of the MTA furnishing is the use of multioperation trailed tools. The number of such tools (machines) trailed in the loop will be smaller, but they are more complex, more expensive, and require more skill of a tractor driver-machine operator.

If we talk about the real possibility of using the multioperation-multiprocess MTA as a tool for improving the efficiency, then the minimum value here would be an opportunity of turning of this MTA virtually in place with a minimum width of the headland. For this, the mounted implements should be used creating, in particular, **two unified mounted systems**, each of which would unite the sets of working organs performing the simultaneous (by time intervals) technological operations.

Fourthly. Based on the use of the two unified mounted systems, a strategic direction of improving the fourth generation of tractors is being established: equipping thereof with two unified independent PTO shafts — a front and a rear one. At the same time, the major expansion of the tractor use according to the load requires that **each** of the PTOs if possible should transmit all the power of the main ICE (because they cannot always work simultaneously). Then, theoretically, a tractor being equipped with the appropriate adapters can not only completely replace some complex agricultural machinery, such as harvesting vehicles, but also take on a number of additional operations, carried out simultaneously with harvesting, which harvesting machines (aggregates) have not yet performed. The prerequisites to such type of integration are now just start being developed [10].

Thus, having synthesized the given four directions (there are still some that are not covered by this paper), we can say that this synthesis will lead to the creation of new fifth-generation tracked vehicles that already cannot be called traditional tractors. We shall call them **mobile power unit**s for agricultural purposes, which have a qualitatively greater range of applications than a traditional tractor.

Thus, it is found out that tracked tractors do not introduce imbalance into the agroecosystem when implementing the technogenic effects introduced by the wheeled tractors participating in the same processes. Therefore, the use of tracked tractors in the product agrotechnologies instead of the wheeled tractors of the same dimensions (mainly according to the traction parameters) seems preferable. The thesis is realistic and supported by the observation of the development of machine-technological support of agribusiness for at least fifty years, that is, with the appearance in mass quantities of heavy wheeled vehicles in the Russian agriculture. Moreover, the inhibition of tracked vehicles development in the last twenty or thirty years failed to stop the work of specialists on the improvement of tracked vehicles. Moreover, even if now, there is a resuscitation of tracked vehicles in the large (as the mathematicians say), and then the notable progress is observed in the technical-engineering recreation. This includes machines of Class 3, Class 5 and 6 "Ruslan", the A-600 tractor with the ICE capacity of 320 h.p. of the **new generation** (a true tractor ICE in contrast to the current actually car ICE) reconstituted on the Rubtsov Plant of Tracked Vehicles. Because of this great work, in the depths there of, the tractor power of the **fifth generation** is maturating.

The mobile power units (MPU) of the fifth generation are designed, in particular, in the Azov-Black See Engineering Institute, FSBEI HE "Don State Agrarian University".

The MPU of the fifth generation of the 50 kN thrust class with the capacity of 220 kW (300 h. p.) and weight up to 10,000 kg has a continuously variable drive of undercarriage providing this MPU with the working forward speed up to 9–12 km/h (0 ... 9–12 km/h) and the transport speed up to 15 km/h. Two unified mounted systems, front and rear, corresponding to the working load capacity of a traditional tractor with the traction of 50 kN, provide for the furnishing of multiprocess MTA capable of combining virtually all technological operations and today not united into a common complex due to the lack of technical facilities, and of implementing them during single pass over the field. For the drive of the mounted (trailed) working bodies, the MPU is equipped with two independent two-stage PTOs (1,000 min^{-1} and 540 min^{-1}), which provide energy transmission through the working bodies up to the full generated ICE of a mobile power unit. Figure 2 shows a model of the new MPU of the named parameters on a scale of 1:12 with two mounted tillage tools on the front and rear mounted systems.

Fig 2: ModelMPU-5300

Figure 3 shows a diagram of MTA based on the MPU-5300 with a mounted forage harvesting adapter (in this case maize harvesting for silage) and an adapter on the rear mounted system to prepare the soil for sowing winter wheat, which prepares the ground simultaneously with harvesting maize for silage. In more detail, the aggregation options are considered in [11].

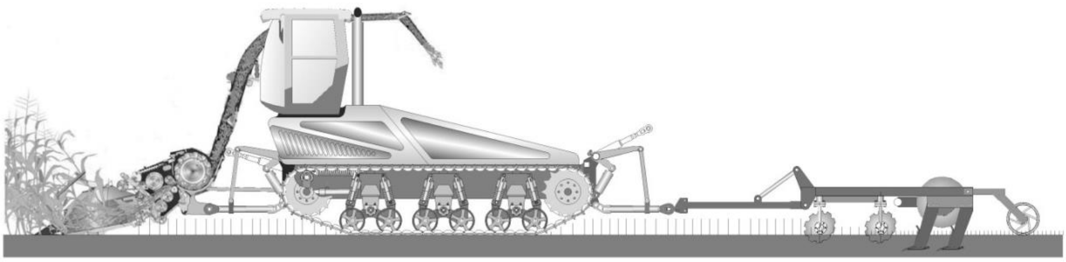

Fig 3: The MTA scheme with a mounted forage harvesting adapter

In order to perform at least a preliminary assessment of the technical and economic efficiency of MPU of the fifth generation in comparison with the existing power units (correct — at least with the fourth generation), we have developed a special methodology, and an economic and mathematical model based on it and intended to perform calculations with the imposition on a typical agricultural organizations with the zonal division of crop rotation, in this case, the grain direction. The fact is that we are concerned in this case not with the comparative effectiveness of MPU in general, but with the **actual efficiency of its construction**, in order to somehow assess the increase of elements that "transform" a developed technical unit into the machine of the **fifth-generation**.

The fundamentals of this special methodology and the examples of its use are given in [12-13]. Based on the estimated data, we found that the number of integrated operations when using the multiprocess MPU-based machinery of the fifth generation — 17 operations — is significantly smaller than in case of using the current technology on the basis of a tractor of the fourth generation — 27 operations, which leads to an increase in the total production for a life cycle of 11 thousand moto hours not less than by 20%.

We emphasize that the use of very expensive specialized machines in a self-propelled version significantly reduces the economic efficiency or negates it completely, which dictates the urgent need for the transition to the use of trailed and mounted non-motorized vehicles-adapters (of course, they still are to be developed, but the same is true for the MPUs).

DISCUSSION

The continuous work on improving the mobile power for agricultural purposes, including the wheeled one, led to a trivial conclusion about the need for significantly expanding the use of tracked vehicles. These machines in terms of their environmental properties have proven their value in mass use. The emergence of heavy wheeled tractors of the "US-Canadian style" since the sixties of the last century was a good negative backdrop for identifying and understanding the benefits of tracked vehicles in practice.

To date, the problem has become aggravated due to the environmental and, in general, systemic reasons. The Russian traditions of using tracked tractors were so indestructible that even during the complete destruction of tractor engineering (the Volgograd and Altai Tractor Plants, and a number of other tractor plants were destroyed), the experts, mainly from the ruins of the National Research University, continued to improve tractors and search for the new schemes that, in particular, led to the development of the fifth generation of MPU.

It appears that the process of commercialization of the fourth-generation tracked tractors of high traction classes and the improvement on this basis of the machine-technological maintenance of agriculture will require a very long period, despite the fact that the design and technological solutions are already available. However, it must be done in view of the need to increase grain production.

No less important is the further development of this issue towards the creation of the **fifth generation of MPU**, as it is planned not only to increase the yield and balance of the technogenic processes, but also to provide the **increase in the sustainability of grain production**. The agroecosystem of the production processes of this most important crop are in the dry grain zone of the country. The preliminary results of studies are given that confirm the reality of achieving the stated goal and solving the given objectives. However, they also predict a long period, which may be preceded by a transfer of a new generation of machines. On the basis of studies on the restoration and replenishment of the tractor park in Russia up to the level of 2001 [14], it can be argued that the nearest time of emerging in the agribusiness of an appreciable amount of tractor machinery of the fifth generation will be 2033–2035. Yet, all the proposed solutions are to be implemented.

CONCLUSION

The prolonged use of highly-productive wheeled tractors of higher power and weight has convincingly proved the negative impact of their undercarriages on the productive soil layers. A highly energy-intensive process of deep loosening of the subsoil layer was brought to life. At the same time, there is a constant danger of breaking the atmospheric moisture accumulated in the topsoil, and the subsoil moisture, which leads to frequent droughts under conditions of arid agriculture. For the last 25–30 years, this phenomenon has increased considerably. The slippage of the wheeled undercarriages in 12–15% leads to the excessive fuel consumption and erosion-prone soils chafing.

The tracked tractors, which formed the basis of the industrialization of agriculture in Russia, are free from the named shortcomings. Now, the USA, implementing the technology of the Russian type organic farming system, still widely use the tracked tractors and already export them. The studies have shown that the tracked vehicles are capable of providing the environmental balance of technogenic operations in the productive agroecosystems.

Findings:

1. The tracked tractors have a range of advantages over the wheeled ones, especially the heavy ones that make the yield, to the category of which the tractors of Class 3–8 belong:
- Provide the enhanced traction coefficient.
- Demonstrate a significantly less slippage and 2–3 times lower ground pressure than the wheeled tractors.
- Do not exhibit a deep influence on the compaction of subsoil layers.
- Do not reduce the productivity on a track as observed in wheeled vehicles.

The synthesis of the benefits of tracked vehicles ensures the ecological balance of technogenic interaction with agroecosystems.

2. The use of the fourth generation tracked tractors in the product complexes of machine technologies as the main power unit shows the possibility to significantly reduce or even eliminate the use of heavy wheeled tractors with all their negative properties.

3. The requirements of ecological balance of the technogenic processes in agrocenoses add a number of new positions into the list of properties of the fifth generation mobile power units and necessitate the creation of the latter: ensuring the possibility of the synthesis of the multiprocess MTA of those operations that according to the agroterm scan be performed at the same time; the presence of a continuously variable drive of undercarriage that enables the possibility of using the total installed capacity both in manual mode of operation and in the automatic mode (in future).

4. The ecological balance of the interaction of technogenic processes with the productive agroecosystems will result in a significant reduction in the technological operations even as compared to the product systems of machines based on of the fourth generation tracked tractors. Due to the furnishing of the multiprocess MTA based on the MPU of the fifth generation, the number of operations is reduced by an average of 40%.

5. Creating the systems of machines with the partial ecological balance of technogenic processes in agrocenoses based on the tracked tractors of the fourth generation can be started from the current moment since the base of power units is virtually available including the heavy tracked tractors of Class 6–7 (tractors T-250 "Alttrak", A-600, "Ruslan"). In as little as5–7 years, the domestic agribusiness may receive a considerable amount of tracked tractors of the fourth generation, which will expand the management of the partly ecologically balanced product complexes and systems of machines.

6. The development of the fifth generation MPU requires longer time since their designing has just begun and yet there are no experimental-industrial samples. A noticeable number of MPUs of the fifth generation with the actual impact on the agribusiness can appear no earlier than in the thirties of the present century.

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