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**ECONOMIC AND ENVIRONMENTAL ASPECTS OF STUDYING THE STABILITY
OF AGROECOSYSTEMS UNDER CONDITIONS OF RISING ANTHROPOGENIC PRESSURE**

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Abstract

Ensuring the sustainable development of agroecosystems requires the study of problems and antinomies of interaction between territorial production systems and agroecosystems. The main goal of the research within the framework of the article is to identify significant contradictions in the interaction of the indicated systems, as well as the paradoxes of their functioning, which will allow us to formulate conceptual provisions for the sustainable environmental and economic development of agricultural territories.

Keywords

Agroecosystem – Sustainable development – Antinomies – Economic and environmental safety

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Introduction

The increase in the anthropogenic load on natural ecosystems is caused by an increase in the profitability of any activity as the natural contribution grows. This is explained by the ability of nature to concentrate energy and substances, transforming them into new forms and creating a basic basis for the formation of geosystems, restoring substances and energy to maintain dynamic equilibrium. At the same time, the emergence of adverse geoecological situations gives rise to the need to search for opportunities to optimize the involvement of the natural resource potential of the territory and maintain the sustainable development of territorial systems.

The current direction of basic research of an agroecological nature consists in studying anthropogenic environmental impacts in the context of increasing intensification of production processes and the formation of integrated approaches to ensuring the sustainable development of agroecosystems.

In the scientific literature, the concept of “agroecosystem” appeared in the 60s. XX century and revealed as a natural-economic territorial complex, functioning on the basis of natural resources. This approach is due to the desire for a holistic perception of systems that are different in their properties and principles of development – territorial-production and geoecological. The formation of ideas about geosystems, agroecosystems and agroecosystems as natural agricultural geosystems first appears in the works of Yu. Odum, V. B. Sochava, V. A. Nikolaev, within the framework of the geosystem concept¹.

Later, at the end of the 20th and beginning of the 21st centuries, a systematic approach developed by A. Zhuchenko, A.N. Kashtanov G.V. Dobrovolsky, V.A. Nikolaev, B.I. Kochurov, V.I. Kiryushin. This approach is based to a greater extent not on unity, but on the interaction of territorial production and agroecosystems. Thus, the “agroecosystem” is a modified natural system involved in agricultural activities and developing both due to natural energy and energy from territorial production systems. The purposeful use of energy can significantly increase the productivity of agroecosystems in comparison with natural ecosystems. Currently, a systematic approach is the basis of almost all the work on the study, assessment, classification, mapping and monitoring of agroecosystems and agrolandscapes².

The formation of integrated approaches to ensure the sustainable development of agroecosystems requires a thorough study of the problems and antinomies of sustainable development in the vector of increasing the ecological and economic safety of agricultural territories, taking into account megatrends of anthropogenic environmental changes.

The main target setting of research in the framework of the article is focused on establishing the existence and identifying the most significant contradictions in the interaction of territorial-production systems and agroecosystems, as well as the paradoxes

¹ V. A. Nikolaev, Fundamentals of the doctrine of agrolandscapes. Agroland-shaft research: methodology, methodology, regional problems (Moscow: Mosk. Gos. Univ, 1992); H. T. Odum, Environmental accounting: EMERGY and environmental decision-making (New York: Wiley, 1996) y V. B. Sochava, Problems of physical geography and geobotany (Novosibirsk: Nauka, 1986).

² V. B. Sochava, Problems of physical geography and geobotany...; A. P. Fedotov, Global studies. The beginnings of science about the modern world (Moscow: Aspekt Press, 2003) y V. S. Chesnokov, “Podolinsky: the concept of social energy”, Century of globalization num 2 (2010): 181–187.

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of their functioning, the awareness of which will allow us to formulate in the future the conceptual provisions for the sustainable environmental and economic development of agricultural territories.

This goal necessitates the solution of a number of tasks: the study of the paradigm of interaction between the natural and social systems, the theoretical assessment of approaches to the interpretation of the concept of “sustainable development”, the study of approaches to the organization and management of the agroecosystem, the study of the possibilities of co-evolution of society and nature by limiting the anthropogenic press.

Methods

The methodological basis of the research presented was a set of general scientific methods: comparative analysis, generalization, abstraction, scientific abstraction, logical analysis, a systematic approach as a general methodological principle of research. The article explores such provisions as assessing the role of natural systems in society, the ratio of anthropogenic load and the potential of the agroecosystem, the imperative of preserving the natural potential, the effect of decoupling, the co-evolution of territorial production and agroecosystems.

Results

Assessment of the role of nature in society's life has repeatedly changed over the course of historical development and was accompanied by a change in the paradigms of interaction between the environment and the public system, which determine conceptual and methodological approaches to the formation of environmental policy, including goals, forms, methods and tools for rationalizing nature management and environmental protection.

To this stage of development, three paradigms have developed in the field of interaction between society and the environment, which are described in the works of Burmatova O.P., Danilova-Danilyana V.I., Loseva K.S., Druzhinina P.V., Moroshkina M.V., Skipperova³. In accordance with the first paradigm that prevailed until the middle of the twentieth century, the natural environment seemed to be an inexhaustible source of natural resources. This paradigm acted as long as the natural environment as a natural prerequisite for the production activity of people ensured economic growth, and the scale of the anthropogenic load on the natural environment fit into the framework of its assimilation capabilities.

With an increase in the consumption of natural resources, the processes of environmental disruption accelerated, primarily its pollution. By the beginning of the second half of the twentieth century, the scale of anthropogenic pressure exceeded the capacity of the natural environment to adapt. It is important to consider not only the scale, but also the

³ O. P. Burmatova, Socio-economic development and a new environmental paradigm. Economics, sociology, law: new challenges and prospects. Int. scientific and practical conf. May 10-15, 2010: in 2 volumes (Moscow, 2010); V. I. Danilov-Danilyan y K. S. Losev, Environmental challenge and sustainable development (Moscow: Progress-Tradition, 2000); P. V. Druzhinin; M. V. Moroshkina y G. T. Shkipperova, Modeling the impact of economic development on the environment (Petrozavodsk: Karelian Scientific Center of the Russian Academy of Sciences, 2009) y O. S. Pchelintsev, Regional economy in the system of sustainable development (Moscow: Nauka, 2004).

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entry into the natural environment of substances of synthetic origin that are alien to it. Under these conditions, the consumer attitude towards the natural environment is being replaced by an awareness of the limited nature of natural resources and the adaptive abilities of the environment.

Thus, by the 50s – 70s of the last century, a second paradigm emerges, which has finally become entrenched in the results of studies by the Club of Rome international non-governmental organization, devoted to studying global processes on the planet and developing tools for managing and overcoming global environmental crises. Under the influence of the development of the indicated views on the process of interaction between society and the environment, from the 80s of the twentieth century the stage of formation of the third paradigm in the field of interaction between the social system and the environment begins.

The natural environment becomes an endogenous factor in relation to the economy and determines the interdependence and interdependence of socio-economic development and the state of the environment. This paradigm is an imperative basis for the formation of the concept of sustainable development, the essence of which is reduced to the claims to preserve and enhance three potentials - natural, technical and human, while improving the technical and technological level of production systems and maintaining the proper quality of the environment. Thus, sustainable development is understood as a systemic unity of wildlife, economy and man in the context of long-term development.

There is no consensus on the interpretation of the concept of "sustainable development" to date. According to the definition in the report "Our Common Future" prepared by the International Commission on Environment and Development, created at the initiative of the United Nations in 1983, sustainable development involves meeting the needs of the present without compromising the ability of future generations to meet their needs⁴.

Therefore, any development should be based on the solution of socio-economic and environmental problems in the framework of the double-win policy. The so-called "decoupling effect", which characterizes the phenomenon of inconsistent trends in economic progress and environmental degradation, is becoming a leading criterion for sustainable development⁵.

That is, the decoupling effect characterizes such an economic growth in which there is no deterioration of environmental indicators. Achieving this effect becomes a priority for the formation of a strategic basis for the sustainable development of agroecosystems. That is, this effect involves the involvement of fewer resources per unit of economic result and a decrease in the negative burden on the environment, which, in turn, necessitates innovative development, the introduction of advanced production and environmental technologies as the main priority for sustainable development.

⁴ Our Common Future: Report of the World Commission on the Environment and Development. 1987. Retrieved from: <https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf>

⁵ Decoupling natural resource use and environmental impacts from economic growth. UNEP. 2011. Retrieved from: <http://wedocs.unep.org/handle/20.500.11822/9816>

In conditions of intensification of agricultural production, paradoxes occur, manifested in the impact on natural ecosystems, proceeding in two directions. On the one hand, these processes create favorable opportunities for the fullest use of the natural potential of agroecosystems through technical and technological advances. On the other hand, such effects lead to dramatic changes in the functioning of agroecosystems, limiting the possibilities for self-regulation and self-healing, violating stability.

Destructive processes are manifested in a decrease in the biological productivity of natural systems, limiting the possibility of stable growth in agricultural production and a decrease in the overall efficiency of agricultural production.

Thus, the environmental and economic aspects of rationalizing the use of natural potential in agroecosystems have close interconnections, which requires complex modeling of phenomena and processes occurring in natural and territorial production systems from the standpoint of their sustainability. Territorial-production systems are managed systems of a socio-economic type, functioning according to social laws and interacting with agroecosystems through the involvement of natural resources in the processes of their activity.

The specifics of the interconnections of the components of territorial production systems is largely determined by the natural properties of the agroecosystem, causing a different degree of reaction of the environment to additional investments of money and labor. When the level of external influence on the agroecosystem deviates, irreversible processes occur that can cause their degradation.

The study of approaches to determining the stability of agroecosystems allowed us to distinguish three main ones. In the first approach, sustainability is considered as the ability of an agroecosystem under the influence of external influences to maintain its properties for a certain time.

The second approach is focused on the explication of the concept of “sustainability” as the ability to retain internal relations that have developed in the agroecosystem during the transition from one state to another. The assertion that the transition of the agroecosystem from one state to another is possible while maintaining internal relations is debatable. The change in the state of geosystems in principle, and agroecosystems in particular, is due to a change in the relationships that have developed between the components of the system.

The third approach reveals the stability property of the agroecosystem through its ability to self-healing after the cessation of external influences. Since the functioning and development of the agroecosystem a priori implies an external impact, this approach does not seem to be completely correct from the standpoint of taking into account the features of its functioning.

The cessation of external influence transfers the agroecosystem into a natural ecosystem, whose vital activity is subject to completely different laws. In the process of transformation, the agroecosystem may degrade, or move to a new level. The evolution of interconnections and relationships of components in the agroecosystem leads to its transition to a qualitatively new level.

Thus, stability in relation to agroecosystems is manifested in the ability to maintain its state, properties and relationships, withstanding external influences for a certain time. In other words, stability consists in the ability to maintain dynamic equilibrium during the functioning of the agroecosystem and interaction with the territorial production system. The dynamics of the development of the territorial-production system is much more intensive than the rate of development of the agroecosystem, and is characterized by an increasing force of impact.

At different stages of development of the described systems, a mismatch of the functional and territorial structures may occur, which causes the transformation of their quality with the violation of the existing equilibrium. These processes take the system to a new quality level. A change in the quality of functioning can have both favorable and critical consequences. In the first case, the economic and environmental parameters of the functioning of the agroecosystem are preserved and can even be improved. In the second case, the internal relations of the functional elements of the system are violated, which leads to a deterioration of economic and environmental parameters and general degradation.

The stability of the agroecosystem is largely determined by the degree of anthropogenic impacts and the ability to free from technogenesis products. Therefore, the concept of “sustainability” is closely related to various aspects of assessing the impact on the agroecosystem of economic activity. The identification of the patterns of interaction between agroecosystems and territorial production systems during the appraisal activity allows predicting the stability parameters for the future taking into account the degree of external impact.

Thus, it is necessary to strive to identify such a level of production intensity that ensures maximum productivity of agrocenoses without disturbing dynamic equilibrium. Establishment of an optimal level of external impact, appropriate from the point of view of the economic and environmental aspect, will allow supporting the sustainable development of the agroecosystem.

The agroecosystem organization methodology used in modern conditions implies their exhaustive exploitation. This is evidenced by various studies, including works devoted to the energy analysis of the functioning of agroecosystems, including publication metrics by authors such as Odum Howard T., Pozdnyakov AV, Fusella T. Sh., Semenova K.A., Chesnokov V.S., Marzhokhova M .A., Halishkhova L.Z.⁶

⁶ M. A. Marzhokhova y L. Z. Halishkhova, “The main approaches to the formation of the strategy of environmental and economic security of the region and the development of a system of measures to ensure it”, Russian Economic Internet Journal num 4 (2016); A. S. Mindrin, Energy-economic assessment of agricultural products: dis. dr. econ. sciences (Moscow, 2003); H. T. Odum, Environmental accounting: EMERGY and environmental decision-making (New York: Wiley, 1996); A. V. Pozdnyakov, “Self-regulation of the floodplain geosystem – dynamics with saturation”, Journal of Wetlands Biodiversity Vol: 3 (2013): 77–89; A. V. Pozdnyakov; T. Sh. Fusella y K. A. Semenova, “Energy assessment of the functioning of agroecosystems with saturation and research objectives. Environmental Management in Sustainable Development: Proceedings of the Intern”, scientific-practical conf. Irkutsk, September 25–29 2017. (Irkutsk, 2017), 130–134; K. A. Semenova, “Quantitative assessment of the bioenergy potential of the Tomsk region. Izv. Tom. Polytechnic un-that”, Geo-Resource Engineering Vol: 323 num 4 (2013): 179–185 y V. S. Chesnokov, “Podolinsky: the concept of social energy”, Century of globalization num 2 (2010): 181–187.

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The modern management structure of agroecosystems does not include controls that are able to dampen productivity growth while achieving a scientifically-based and practically verified maximum productivity. Achieving this level implies a transition to intensive methods of activity while simultaneously introducing mechanisms aimed at maintaining and strengthening the sustainability of the agroecosystem.

Thus, the activity of the territorial-production system should be anti-entropic for the agroecosystem as a whole, since its energy contribution to the final product is decisive. The introduction of such controls implies a fundamental transformation of the set development goals of the agroecosystem. In traditional versions of the organization of management of agroecosystems, attractive goals are determined by the market and the personal interests of management entities.

A new approach to management should, in our view, be based on a “supply-demand” installation in the agroecosystem. At first glance, this may seem paradoxical, but within the agroecosystem there is demand, which is a kind of paradigm of the structure, not destroying, but supporting the state and forming feedback.

Thus, the preset state of the agroecosystem will not only represent a qualitatively-quantitative level of products that it should reach after a certain time, taking into account the intended parameters of profitability, but also the introduction of criteria for stability and productivity of the system, taking into account biological diversity and a qualitative improvement of all output characteristics system. Such an approach requires the application of new principles for organizing the functioning of agroecosystems and their transition from the category of economic systems to the category of ecological and economic systems with an increase in the status of agroecosystems.

The expression and structuring of the ideas of sustainable development of agroecosystems, focuses the attention of researchers, primarily on the magnitude of anthropogenic impact (pressure) and the search for ways to reduce it. In the works of A.P. Fedotova proposes the introduction of quantitative criteria into the concept of sustainable development, which will measure the sustainability of development, as well as constructively direct it. Recognizing the importance of the quantitative approach, we still believe that the most important characteristic of sustainable development is the specifics of the interaction of the territorial-production system and the agroecosystem taking into account the anthropogenic press.

The decrease in the anthropogenic press in old-developed agroecosystems and the establishment of an optimal load in newly mastered ones is due to the presence of limits and limited opportunities to satisfy needs. The attractive goal is to recognize these limits and organize anthropogenic activities within the carrying capacity of the ecosystem.

The most appropriate and general for the assessment of anthropogenic pressure are energy units. They more fully characterize the pressure of the territorial-production system on the agroecosystem and summarize all types of impacts. The development of quantitative criteria for anthropogenic press on the ecosystem is associated with determining the actual impact and comparing it with the maximum permissible parameter.

For this kind of approach, the concept of the carrying capacity of an ecosystem in which the mentioned limits and limitations are contained is methodologically initial. Development is recognized as sustainable if it does not violate the limits of permissible

disturbance of the agroecosystem. Moreover, these limits are determined within the framework of a biosphere, resource or other model of the interaction of nature and man. The above allows us to formulate the conclusion that the transition to sustainable development acts primarily as a transition from spontaneous management to scientifically based, with the possibility of introducing restrictions on the spontaneous anthropogenic process that would keep it within the bearing capacity of the agroecosystem.

The restriction of the anthropogenic press on the agroecosystem is the starting point of the transformations that must be adopted for the transition to sustainable development. These transformations can affect not only the basic aspects of the interaction of nature and society, but also society itself.

The reduction of the anthropogenic press and the intrasystemic transformations that contribute to this pursue the goal of development through preserving the mutual security of society and nature, that is, through mutual development, or socio-natural co-evolution. At the same time, co-evolution of society and nature as their co-development is possible only if society, developing progressively, will take resources from nature and exist in an acceptable enough stable environmental condition.

But in interacting systems there is a process of disproportionation of entropy: a decrease in entropy in one system is associated with an increase in it in another.

If we consider progress as a process of increasing complexity of self-organization and an increase in the level of orderliness of systems, then it is clear that in nature and in society these processes go completely differently. In the case of a progressive version of the development of society, regressive processes occur in nature, since its resources are withdrawn, which simplifies and disorganizes the ecosystem. Thus, co-evolution, that is, joint co-development, suggests that the progress of society is achieved through the regression of nature and there can be no joint progress. In this regard, the statements of V.I. Danilova-Danilyana on the impossibility of applying the concept of “co-evolution of society and nature” in a sense is justified⁷. At the same time N.N. Moiseev defines co-evolution as the co-development of an element and a system in which the development of an element does not violate the development of the system⁸. Therefore, if anthropogenic impacts do not exceed the compensatory capabilities of the agroecosystem, co-evolution is possible. In this case, society also withdraws natural resources, but does so within the load-bearing capacity of the agroecosystem, which does not lead to significant disruptions in its development and does not impede evolution. In both cases, the progress of society is achieved through natural resources, which implies degradation of nature.

In the case of sustainable development, the degradation of the agroecosystem is minimal, therefore, in our opinion, it is permissible to talk about co-evolution of society and nature. We consider the sustainable type of development relatively safe for the agroecosystem, since it is designed in such a way as to ensure this security by organically incorporating its parameters into the development process.

⁷ V. I. Danilov-Danilyan y K. S. Losev, Environmental challenge and sustainable development. (Moscow: Progress-Tradition, 2000).

⁸ N. N. Moiseev, The fate of civilization. The path of the mind (Moscow: Languages of Russian literature, 2000).

The reduction of the previously mentioned contradictions is achieved by combining progress and security within the framework of a sustainable development option. In this case, it also becomes possible to ensure ahead of schedule the safety of the components of the agroecosystem, which will optimize the costs of such provision in comparison with the current approach to eliminating the consequences of disturbance of agroecosystems.

The modern model for the development of territorial production systems is mainly of an economocentric nature, causing negative consequences for agroecosystems. The economy focuses mainly on business processes, that is, relations regarding the production, exchange, distribution and consumption of material goods.

Industrial relations are considered as occurring within society and traditional economic science is abstracted from social, environmental and other relations and consequences, which ultimately affect the economy. This model symbolizes the concept of economic efficiency.

The transition to a model of sustainable development as a management process can be symbolically represented as the introduction of restrictions on the spontaneous market process, which will reduce the negative consequences for agroecosystems. Restrictions are also imposed on the economic process, which can no longer be carried out along an extensive trajectory. In order to organically fit into the system of sustainable development, the economic process must be transferred to an intensive development path when efficiency growth will occur due to qualitative factors, and not to go along the path of expanding the space of activity and quantitative factors.

Thus, a sustainable agroecosystem economy can be defined as an economy implemented along the path of intensively innovative development, significantly optimizing the quantitative parameters of the natural resources involved, as well as technogenesis products, accompanied by social and biosphere-ecological constraints. Formulating the foundations of sustainable development of agroecosystems means the gradual integration into a single self-organizing system of economic, environmental and social spheres of activity.

In this sense, the sustainable development of the agroecosystem should at least be characterized by economic efficiency and biosphere compatibility with a general decrease in the anthropogenic pressure on the biosphere.

Discussion

In the course of the study, the most significant contradictions in the interaction of territorial-production systems and agroecosystems were identified and described, paradoxes in their functioning were examined. Awareness of the identified antinomies will make it possible to more specifically formulate conceptual provisions for the sustainable ecological and economic development of agricultural territories.

Studies show that there is a significant potential for self-healing of agroecosystems, but they have certain limits. Exceeding these limits leads to an imbalance in the agroecosystem, a decrease in its productivity and accelerating environmental degradation. This limit is called the stability limit of agroecosystems or bearing capacity, and it is individual for each ecosystem individually.

In this regard, the basis of the mechanisms of organization and management of agroecosystems should be the ratio between socio-economic development and the limits of the economic capacity of the agroecosystem, the excess of which will lead to the destruction of the natural biotic regulation of the environment. Thus, the aforementioned correlations, their assessment and scientifically based conclusions must be taken into account when forming normative and methodological documentation on the problems of sustainable development of agroecosystems.

Awareness of the identified antinomies of the interaction of territorial production systems and agroecosystems will make it possible to further apply them in the framework of formulating conceptual provisions for sustainable ecological and economic development of agricultural territories, generalizing approaches to defining the concept of “the phenomenon of agroecosystem sustainability”, analyzing general patterns and trends of anthropogenic environmental changes, identifying trends and factors determining agricultural nature management in the regional development. Here, substantiation of the methodological aspects of the analysis of the influence of environmental factors on the development and formation of territorial agroecosystems.

Conclusion

The main brief results of the studies are reduced to the following provisions:

1. The imperative basis for the formation and implementation of the concept of sustainable development is the paradigm in which the natural environment is recognized as an endogenous factor in relation to economic systems and its load-bearing ability to underlie the formation of parameters of socio-economic development.

2. The fundamental criterion for the sustainable development of natural-economic systems, including agroecosystems, is to achieve the “decoupling effect” in the ratio of economic growth and environmental status, which will serve as a strategic basis for the formation of sustainability and innovative development parameters.

3. The research presented in the article is based on the interaction of territorial production systems and agroecosystems not on unity, but also on the interdependence of their sustainable development.

4. The natural properties of agroecosystems determine the interconnection of components in territorial production systems, as well as the nature and degree of reaction of the environment to new investments of funds and labor.

5. Stability in relation to agroecosystems is defined by us as its ability to maintain dynamic equilibrium, withstanding external influences for a certain time.

6. Evaluation activities in the framework of the interaction of agroecosystems and territorial production systems have close interconnections with the stability properties of agroecosystems and allow predicting their parameters taking into account the degree of external influences. Studies based on various principles of valuation and analytical activity indicate a depleting option for the operation of agroecosystems. Maintaining the sustainable development of agroecosystems requires identifying the level of intensity of impacts from territorial production systems in order to maintain dynamic equilibrium.

7. Ensuring the sustainability of the development of agroecosystems requires introducing elements into modern management systems that are capable of damping productivity growth while achieving a scientifically based and practically verified maximum productivity. Such an approach will ensure the transition of the agroecosystem from the economic category to the category of ecological and economic system with increasing status. Thus, the transition to sustainable development acts as a transition from elemental management to science-based, which will limit the spontaneous anthropogenic process and keep it within the bearing capacity of the agroecosystem.

8. The transition to a sustainable type of development requires restricting the anthropogenic press within the compensatory capabilities of the agroecosystem. Intra-systemic transformations of this kind pursue the goal of development through preserving the mutual security of society and nature, that is, through mutual development, or social-natural co-evolution. In this case, it also becomes possible to ensure ahead of schedule the safety of the components of the agroecosystem, which will optimize the costs of such provision in comparison with the current approach to eliminating the consequences of disturbance of agroecosystems.

9. The modern model for the development of territorial production systems is mainly of an economocentric nature, causing negative consequences for agroecosystems. This model symbolizes the concept of economic efficiency.

10. A sustainable economy can be defined as an economy implemented along the path of intensively innovative development, significantly optimizing the quantitative parameters of the natural resources involved, as well as technogenesis products, accompanied by social and biosphere-ecological constraints.

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