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Economics of nature protection and resource conservation from the Russian Empire to the USSR: Achievements, failures, and conflicts

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Abstract

Considering the attention paid to nature protection throughout the history of economics, it would be worthwhile to evaluate the scientific thought in the Russian Empire, the USSR and Russia concerning an environmentally oriented economy. The review presents an analysis of research works on this topic — from Vernadsky's concept of the biosphere and environmentally oriented management in the USSR to the modern scientists' ideas. In the USSR, economics of nature conservation studied the strongest interconnections between society and the ecological environment for further depleting and preventing pollution. The study identifies the leading researchers and outlines the main concepts of how the economy can reflect environmental protection and support sustainability.

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Introduction

It has been a long journey from the classical economy to the environmental economy (Daly, 2005). Researchers specializing in the history of the subject, such as Pearce (Pearce, 2002), trace its origins to the 1960s (Pierce, 1992). However, "early history" actually refers to literature published before the 1960s (Sandmo, 2015). As the functioning of economic systems becomes more complex, the role of the ecological factor is permanently growing (Khachaturov, 1987).

The study of the significance, role and place of the natural (ecological) factor in the economy is the subject of ecological economics. The German term Ökologie was first used by the German biologist Haeckel (1869) (Richards, 2006). A little later, its English equivalent ("ecology") appeared. Ecology (from the Greek *oikos* meaning "house," "dwelling," "habitat," and *logos* meaning "doctrine") is the science of the nature management and the life of organisms (according to Haeckel). Thus, ecology is a science that studies the entire complex of relationships in nature. Economics (from the Greek οικονομικη) is the art of housekeeping (Gutiérrez-Aragón & Fondevila-Gascón, 2017). Thus, historically, the concepts of "economy" and "ecology" are already clearly interconnected. The term "economics" is used to identify patterns of the "economic" functioning of society, while "ecology" is used to search for the "economic" development of the relationship "organism — environment." Nature (Biosphere) <=> society (socium) is a complex interrelated link between ecology and economy (Gare, 2002). Lamarck said that in the following centuries, man would destroy himself by damaging his environment. Malthus emphasized the idea of exponential population growth and the problem of overpopulation. Darwin, a follower of Malthus, formulated provisions on the struggle for existence and natural selection. In his work "Cosmos," Humboldt used the words "life sphere," where "in this grandiose sequence of causes and effects, nothing can be considered in isolation" (Mirkin, 2011). In Germany, the principles of sustainability came into use in the Middle Ages. The German word "Nachhaltigkeit" (sustainability) has been used in forestry management since the 19th century (Ursul, 2004).

In early 1962, Rachel Carlson, an American woman scientist, began the prologue to her book "Silent Spring," published in the 1970s by Dr. Dennis L. Meadows (Meadows et al. 2005), with the Green Revolution. "Limits to Growth" by Meadows is the Club of Rome's first attempt at analyzing economic development using a conservation model. In 1989, the "Blue Book Green Economy," written by the British economist Pierce, began the era of "green" economy, which postulated that the entry into the 21st century with its informatization, network technologies, and high-tech revolutions that increased the likelihood of an environmental crisis was characterized by a lack of resources, environmental pollution, and environmental imbalance (Pierce, 1992). Coarse

(1960) analyzed how industrial companies harmed others (Ollivier, 2009). Farley and Voinov argued that our main economic challenge was to maintain the current socio-ecological regime's resilience. People must reduce the negative economic impact to eliminate critical ecological level (Farley & Voinov, 2016). The practical aspect of environmental economics combines the following groups of problems: the economic assessment of natural benefits, the economic damage evaluation, and ways to include the environmental factor in the socio-economic mechanism (Khachaturov, 1987). As Daly pointed out, economic growth was directly related to a decline in social responsibility and increased pressure on ecosystems (Daly & Farley, 2004; Daly, 2005). Costanza et al. advocate the development of ecosystem services (Costanza et al., 1989; Costanza et al., 2014) and timely regulation of the situation by the countries' or companies' management. They emphasized that humanity would benefit from tracking ecosystem services (Costanza et al., 2017).

Ecological economy axioms: (1) it is impossible to expand the sphere of influence in a confined space; (2) everything on the planet is interconnected (Steblyanskaya et al., 2019); (3) environmental economics is a systemic vision of sustainability (Costanza et al., 1989; Khachaturov, 1987); (4) it is impossible to endlessly increase needs in conditions of limited resources (Daly, 2005; Meadows et al., 2005).

The Russian Federation is the largest country on Earth. As such, its environmental problems and policies have global consequences. However, assessing the quality of Russia's environment and its environmental policies is a challenging task (Henry & Douhovnikoff, 2008). Indeed, the USSR was a closed country, where, unfortunately, scientists were not allowed to communicate with international scientists, thus, the ecological economy thought developed at the regional level. In the USSR, the economy of nature conservation (ekonomika prirodopol'zovaniya) developed as an economic branch since the 1970s and was based primarily on observations of agricultural economics (Bobylev, 2005; Lukyanchikov & Bobylev, 2009). The term "nature management" was introduced by Academician Kurazhkovskiy in 1959. As for environmental management economics, it is the art of economic management that ensures harmonious interaction in the "society — nature" system. It solves the problem of rational management, taking into account environmental factors and economic interests of society (Kurazhkovskiy, 1969). Considering the attention paid to ecological protection throughout the history of economics, the study describes the thoughts and concerns about environmentally oriented economics present in the scientific works of the Russian Empire, the USSR, and Russia.

The paper aims to consider Russia's environmental economy from the Russian Empire to the late USSR. The study's primary tasks are:

- Classification of the stages of development of the ecological economy of the Russian Empire and the USSR
- Identification of the most prominent researchers and foresight ideas related to economics and environmental protection
- Classification of the nature protection and resource conservation thought as an essential component of the environmentally oriented development (Kiang, 2003; Mishra, 1990).

In this paper, the authors use classification methodology to analyze the development stages of the environmental economy and the main directions of the scientific thought in this field in the USSR.

1. Ecological ideas in the Russian Empire

Rouillier, a professor at Moscow University, wrote: "No organic being lives on its own; each one is called to live only insofar as it is in relationship with a relatively external world for him." Roullier was a prominent lecturer who advocated studying animals in terms of their relations with the environment and the limits of fossil fuels. One of his most famous students and followers was Bogdanov (Mirkin, 2011). Bogdanov investigated the links between the environment and society in the framework of the noosphere paradigm (Bogdanov, 1989). Bogdanov's "Tektology" described the links between nature and society that can be investigated using organizational methods. Bogdanov's "Tektology" represents a unique contribution to organizational theory and practice. The concept of "biosphere" was developed by the Russian scientist Vernadsky. According to his definition, the biosphere is the Earth's shell inhabited by living organisms and qualitatively transformed by them. It is the most extensive (global) environmental system on the planet. The biosphere includes the atmosphere, hydrosphere, and lithosphere and living organisms inhabiting them (Bischof, 2007). The concept of "noosphere" was introduced in 1927 by the French philosopher Leroy and meant a thinking shell or a sphere of reason. However, the modern understanding of the noosphere was formulated by Vernadsky (Bischof, 2007). Along with the concept of "biogeocenosis," a similar concept of "ecological system" is used. The ecological system consists of two components: organic (biocenosis) and inorganic (biotope) (Vernadsky, 2012). It has the ability to self-regulation, self-support, and self-healing. If this ability is violated, the ecological system's degradation and death begins (Khoreva, 2014). Assimilation potential is the environment's ability to receive, recycle, and neutralize production and consumption waste. Exhaustion of the assimilation potential of the environment is a constraint on socio-economic development. In other words, exceeding the threshold loads on ecological systems depletes their assimilation potential. The noosphere's thought develops on the basis of the harmony of nature, but considers it as a whole with the cycle of matter and energy (Bischof, 2007). In the Russian Empire (and later in the USSR), the founder of theoretical cosmonautics Tsiolkovsky thought about the survival of the human race. He put forward the idea of life in extraterrestrial spaces, and, with the help of space exploration, determined the possibility of continuous progress of civilization and thereby ensuring the immortality of the human race (Dvornychenko, 1990).

Academician Strumilin began his scientific and journalistic activities in 1897. His first book, "Wealth and Labor" (1905), contains a deep political and economic analysis of the Russian reality. The scientist was convinced that construction of plans should be based on balancing economic development, preserving nature, balancing and bringing resources in line with human needs (Fedorenko, 1977). Strumilin created a model of optimal savings

(Figure 1), where he answered how to solve the problems of time horizon or the preference of future consumption over present consumption (Klundert & Klok, 1966).

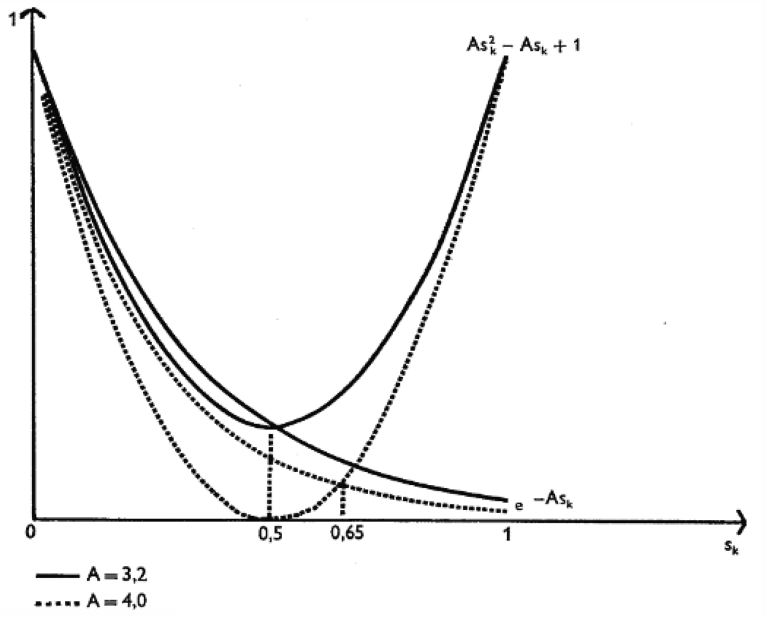


Figure 1. Strumilin's model: optimal savings for the value A

The "Great Reforms" of the 1850–1870s spurred the industrial and economic growth in the Russian Empire, where four all-Russian and seven regional public organizations were founded to preserve the country's natural resources and develop rational and balanced practices of nature management. Chairman of the Imperial Society of Fisheries and Fish Farming, Professor Grimm, calculated the damage to fish resources from oil transportation along the river Volga, which accounted for half of the country's total fish catch. Grimm and the Society' s scientific and educational campaign provoked an investigation in the Natural Department, and on May 27, 1904, a restrictive law against transport pollution of the Caspian-Volga routes was adopted.

2. History of the environmentally oriented economy in the USSR

Despite the long-term dominance of the dogma of free use of natural resources, elements of paid use of natural resources were slowly and half-heartedly introduced into the economic practice of the post-war period. In 1949, the fee-based procedure for cutting down forest stands, eliminated in the 1930s, was restored. In the 1970s, a regime was introduced obliging to pay for the consumption of mineral resources during their extraction, and in 1982, a payment obligation for the use of water resources was introduced. However, under the previous economic conditions, the liabilities of nature users to the state were

purely formal, not related to the real redistribution of the rights of the state and nature users in terms of the disposal of property on resources. Gofman argued that it should have been a simultaneous introduction of two types of payments for natural resources — for their consumption and the right to use natural objects within a given territory (Fischer-Kowalski, 2007).

Soviet scientists first conducted an audit analysis of the natural environment after the UN conference in Stockholm in 1972 (Lukyanchikov & Bobylev, 2009). Basing on this report, a resolution "On measures to strengthen nature protection and improve the use of natural resources of the USSR" was adopted on December 29, 1972. Since that time, nature conservation measures were included in the USSR's state plans for the country's social and economic development. The Interdepartmental Scientific and Technical Council on complex environmental problems was created, where the most acute environmental problems were considered: the shallowing of the Aral Sea, the fall in the level of the Caspian Sea, the pollution of Lake Baikal, and the violation of the salt regime of the waters of the Azov Sea. The growing activity of the environmental movement in the country received a powerful impetus.

In the 1970s and 1980s, scientific schools in environmental economics were established: at the Central Economic Mathematical Institute of the Russian Academy of Science (CEMI RAS) under the guidance of Academician Fedorenko, at Moscow State University (LMSU) under the guidance of Academician Khachaturov, and in Sumy under the guidance of Professor Balatsky (Balatsky, 1984). During this period, as part of the Free Economic Society of Russia, the "Economics of Environmental Management" section was created, since it was considered the most pressing issue in the rational use of resources. Academician Fedorenko developed the discipline of accounting and use of Russia's natural resources (Urinson, 2012). However, not all measures of protection and reproduction of nature's benefits can be approached with a purely economic yardstick. For example, it is still unclear how to apply calculations to certain anthropogenic impacts on nature. For example, how to assess the already noticeable influence of power lines on the Earth's magnetic field? In some situations, preservation or improvement of nature's benefits should be considered a social standard, rather than discussed in terms of economic benefits. If we are talking about eliminating pollution that is hazardous to human health or preserving unique natural complexes, such as Belovezhskaya Pushcha, then the role of the economist is relatively modest: the economist should not decide whether this environmental measure is beneficial or unprofitable, but suggest how to implement the environmental protection measure with minimal costs. And it is not necessary to know what the cost in rubles and kopecks is, for example, of such rare species of animals subject to protection as the Bialowieza bison. Consequently, there is no need for an economic assessment of natural objects that cannot be called resources. Nevertheless, this is just an exception to the rule. The rule is the need to create a system of economic assessment of all natural resources (Fedorenko, 2000). The first work on the economic assessment of natural resources began at CEMI RAS in the framework of a new theory called the System of Optimal Functioning of the Economy (SOFE). CEMI RAS scientists developed a system of optimal functioning of the economy, where the assessment of

natural resources was the crucial concept of the theory of optimal economic functioning. According to this system, all factors involved in the production should be evaluated by their contribution following the optimality criterion. Following the principles of this theory, in 1970, researchers from CEMI began work on the economic assessment of land and natural resources. The most significant event of that period was the publication of the Resolution of the Central Committee of the CPSU of January 7, 1988, No. 32 "On the restructuring of environmental protection in the country" that implemented ecological methods in companies and prescribed effective cooperation with foreigners (Lukyanchikov &Bobylev, 2009).

According to some experts, nature conservation and environmental policy in Russia dates back to the period of the formation of the Russian state, when unique hunting "orders" were mentioned in the annals. For others, it was quite logical to count the formation of the management of reserves from the princely hunts in the Kuban and in the Belovezhskaya Pushcha. Furthermore, there is no better beginning of the state's zeal for protecting nature than the decrees of Peter I on the preservation of ship groves and pine forests along the banks of Central Russian rivers. Soviet scientists for more than 70 years were sure that territorial nature protection originates from Lenin's decrees on the creation of the "Astrakhan" and "Ilmen" nature reserves. We are only now beginning to realize the depth and power of the initiatives aimed at protecting ecological heritage of Russia undertaken by the Russian Geographical Society in the late 19th — early 20th centuries (Tishkov, 2017).

3. Stages of environmentally oriented development of society in the Russian Empire and the USSR

Experts distinguish various stages of the formation and development of the environmental policy in the USSR, which practically coincide with the stages of the society's socio-economic development (Table 1).

Table 1. Development of resource conservation economics in the USSR

Period	Main events	Legislation acts
1917 — late 1920s	Prerequisites for the formation of the legislative framework	Formation of environmental management. The Permanent Environmental Commission under the Russian Geographical Society was organized and successfully operated from 1920 to 1930
Early 1930s — first half of 1950s	Sharp deterioration of the environment and destruction of natural balance	Introduction of environmental policy legislation. "Destruction" of reserves by Stalin (1951) and Khrushchev (1958), followed by the establishment of the Nature Protection Commission under the Academy of Sciences with a "Long-term plan for the USSR geographical network of reserves" (1958)

Table 1. Continued

Period	Main events	Legislation acts
1960 — early 1970s	Development of mechanisms for environmental assessment and ecological protection control. More attention to the environmental financing models	The Law "On Nature Protection in the RSFSR" (December, 1960)
Late 1970s — late 1980s	(1) Significant increase in the role of the state in regulating nature protection issues; (2) Noticeable improvement in environmental legislation; (3) Substantial government support and development of environmental research; (4) Evaluation of projects in terms of maximum permissible concentrations of harmful substances	Due to the sharp deterioration of the ecological situation in the country in the 1970s and 1980s, a number of laws and regulations were adopted aimed at preventing environmental pollution. In 1988, the USSR State Committee for Nature Protection was created, along with its republican and local subdivisions. Restoration of the reserves' evaluation
1990s	Introduction of a new green tax system. Formation of legislation incorporated into the international system. Creation of a network of specially protected natural reserves	In the field of environmental protection, the main document is the Law of the RSFSR dated December 19, 1991 No. 2060-1 "On environmental protection" (with amendments and additions dated February 21, 1992 and June 2, 1993). The RF also follows the Law "On the protection of atmospheric air" (1996), the Law "On Subsoil" (1995), etc. The Law "On Environmental Expertise" was adopted in 1995

Source: compiled by the authors, (Tishkov, 2017).

The interconnection between the state, society and nature has deep historical roots, and its origins are associated with the political, economic and cultural evolution of humankind. In Russia, these relationships were not easy to build over several eras: pre-revolutionary, Soviet, and post-Soviet. In the Soviet era, we observed immediate changes: (1) in October 1960, the Law "On Nature Protection in the RSFSR" was adopted, which entailed many changes in the environmental management system and control over nature conservation, and (2) in December 1960, the first student nature conservation society, the leading Russian environmental movement, was established at Moscow State University. Furthermore, in the same 1960, another important event took place — a genuinely large-scale movement "For Leninist attitude to nature" was born, which gradually embraced enterprises, organizations and institutions throughout the country (Makeeva, 2017).

The first environmental protection act was initiated in 1947 in Great Britain and was related to land planning. In the late 1950s, the US Congress reacted to increasing public concern about environmental issues. The first USA ecological law was the National

Environmental Policy Act of 1969 (NEPA, 42 U.S.C. §§ 4321-4347),[1] followed by the Clean Air Act,[2] and the Clean Water Act.[3] In Canada, the 1969 Throne Speech foreshadowed the passage of five new environmental statutes, including the Clean Water Act, the Clean Air Act, the Environmental Contaminants Act, and the Ocean Dumping Control Act (most of which were eventually merged into the Canadian Environmental Protection Act) in the early 1970s (Emrouznejad et al., 2016). In Japan, the environmental protection law was passed in 1964. A similar law was implemented in Great Britain in 1971. In France, the same law was adopted on July 10, 1976, and since 1974, the principal scheme of ecological protection assessment has been implemented. The USSR was one of the first countries to launch this law, and it significantly strengthened legislative activities in the field of environmental protection. However, in the USSR, there was a weakness of state branches in implementing environmental legislation and insufficient financing of environmental protection measures (Sand, 2015).

In the USSR, nature management was understood as an area of interaction between society and the environment, covering the processes of mastering and transforming objects and forces of nature to meet human needs. Nature management, or the economy of nature conservation, was divided into three research areas (Table 2).

There were the following principles of nature management: (1) maximization of social benefits of natural resources; (2) expanded reproduction of natural resources; (3) green production.

Table 2. Research areas of nature protection and resource conservation in the USSR

Research area	Research subject	Process
Natural resource economics	Problems of effective use of natural resources in the conditions of different types of economics and different natural and climatic zones of the Earth	Stage 1 — resource extraction and processing
Pollution economics (waste management economics)	Processes of using such a unique resource of nature as assimilation (absorbing) potential. It is essential to analyze the volume of pollution with minimal damage to nature, and the optimal absorbing potential of the environment	Stage 2 — removal of production waste
Conservation economics	Economic features of environmental protection	Stage 3 — restoration and protection of natural resources

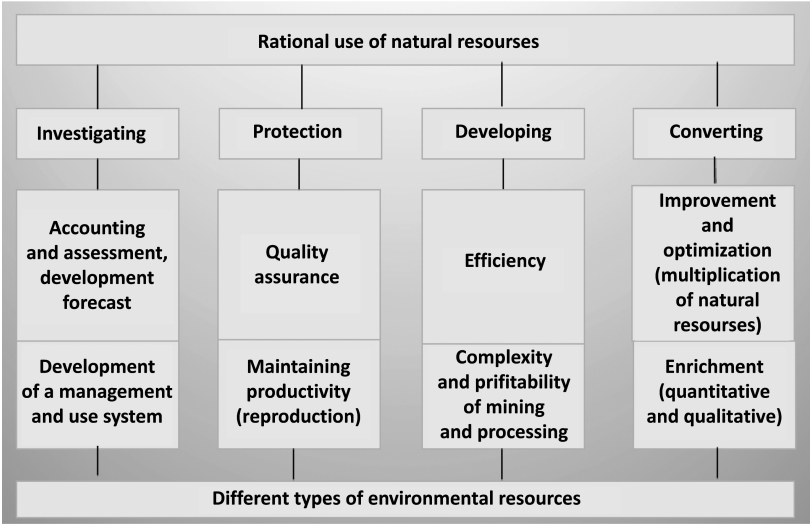
In the USSR, economics of environmental management, along with general scientific and general economic methods of analysis, widely used the following special methods

[1] CRS Report for Congress. The National Environmental Policy Act: Background and Implementation. February 29, 2008. Linda Luther https://fas.org/sgp/crs/misc/RL33152.pdf

[2] https://www.epa.gov/clean-air-act-overview

[3] https://www.epa.gov/laws-regulations/summary-clean-water-act

(Khachaturov, 1987): (1) static and dynamic modeling; (2) balance approach and cost-benefit analysis; (3) methods of optimization and limit analysis; (4) methods of probability theory and mathematical statistics; (5) program-targeted approach; (6) game theory tools. When carrying out economic, managerial and other activities that harm the environment, it is necessary to observe the rules in the field of environmental protection (Oldak, 1963): (1) protection of humanity; (2) rational use of resources; (3) compliance with ecological legislation; (4) openness in work and close communication with public organizations and the population in solving environmental problems (Figure 2).

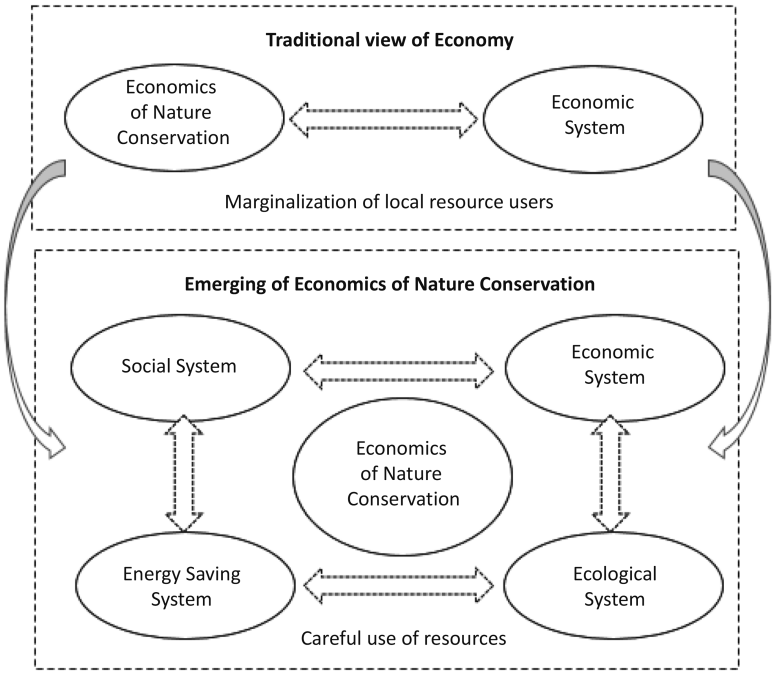


Source: (Khachaturov, 1987).

Figure 2. The environmental management principles in the USSR

4. The main scientific ideas concerning the development of environmental economics in the USSR

According to Armand, the moral duty of each generation is to leave the planet to the next generation in a better condition than it was received from previous generations. His book "To Us and Grandchildren" was published in 1964. For the Soviet reader, this work was destined to become almost the same as Dorst's book "Before Nature Dies" was for the Western reader. For the first time in Soviet literature, Armand outlined the scientific methods of nature conservation, designated natural resources as an absolute value for humans, and argued for preventing waste and neglect of the importance of nature. Armand persistently and categorically rejected speculative attempts to avoid solving this issue. "The theory that now, at the tense moment of building communism, we can make a "loan" from nature, that our children will live better and then they will return the debt to nature... This is not wise and not courageous theory." A schematic diagram of the USSR's economics of nature protection and resource conservation is presented in Figure 3.



Source: compiled by the authors.

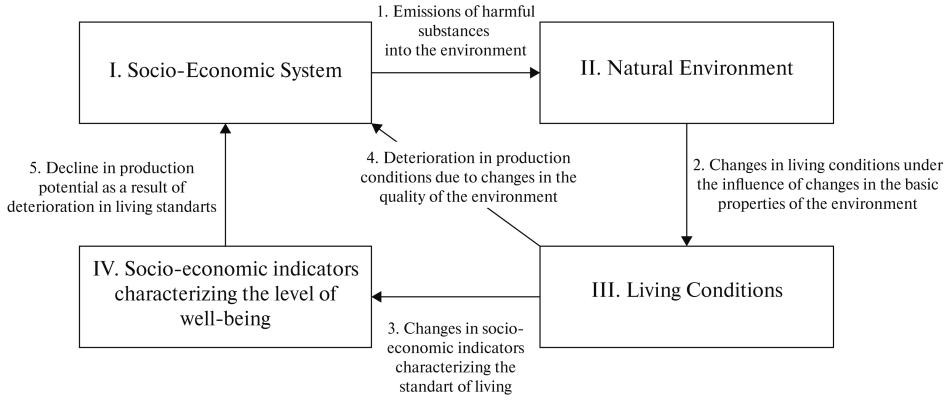
Figure 3. Schematic diagram of the USSR's economics of nature protection and resource conservation

Figure 3 shows the difference between the traditional vision of the economy and the Soviet economy of nature conservation. In contrast to the conventional approach to environmental protection, the USSR's economy of nature conservation uses social, ecological, energy-related, and economic factors.

Addressing the problem of optimal proportions (van de Klundert & Klok, 1966), Strumilin points out that natural capital must be calculated in the same way as monetary capital. Strumilin's model of optimal saving can be used to calculate optimal natural capital savings.

Danilov-Danilyan dealt with the issues of payment for the impact of waste on the environment while using natural resources, the effectiveness of capital investments and the use of trailing commissions costs. He also researched the preservation of the Amur River and investigated the disastrous flooding in the Amur basin (Danilov-Danilyan et al., 2014; Gotovtsev et al., 2012). He emphasizes that the concept of the biosphere' s economic capacity should be taken as the basis for the sustainable development. This concept characterizes the limit of the anthropogenic impact on the environment, exceeding which entails its irreversible changes that threaten the survival of humans as a biological species (Danilov-Danilyan et al., 2014).

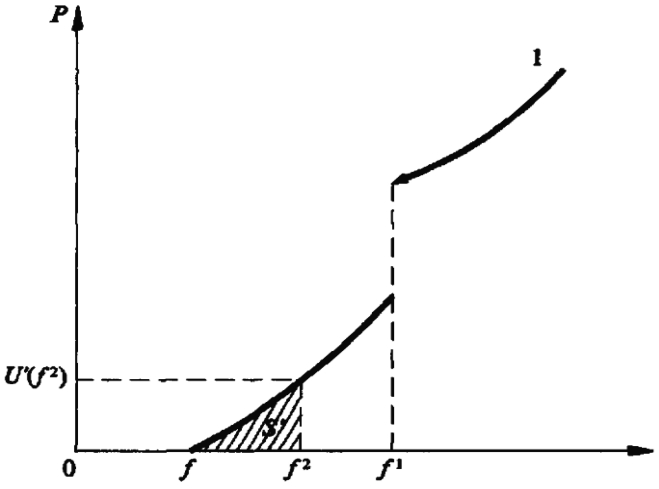
In their book "Nature Management," Golub and Strukova (Golub & Strukova, 1995) emphasize that every production activity is closely linked with its impact on the environment (Figure 4, 5).



Source: (Golub & Strukova, 1995).

Figure 4. The mechanism of damage caused by pollution

Among the first studies in the field of conservation economics conducted at the Kola Scientific Center of the Academy of Sciences of the USSR the following can be named: (1) Assessment of the economic efficiency of the scheme for using recycled water supply (1974, 1976); (2) Development of methods of measures to prevent water bodies' pollution in the region (1981). In the 1970s and 1980s, the share of the USSR's budget expenses on environmental protection reached a historical maximum. The USSR's environmental legislation consisted of four volumes of legal acts. The "Territorial environmental planning schemes for the period up to 2000" were developed, taking into account the environmental statistics of enterprises.



Note: f is the natural environment's assimilation capacity, *l* — marginal damage from environmental pollution.

Source: (Golub & Strukova, 1995).

Figure 5. Economic optimum of environmental pollution

For the list of Soviet and Russian researchers, see Table 3.

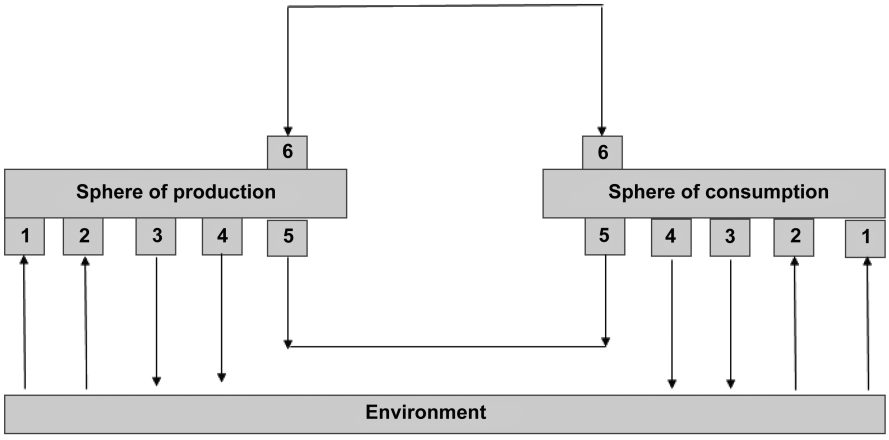
Table 3. List of Soviet and Russian researchers in the field of environmentally oriented economics

Author	Main Concepts	Year
Kurazhkovskiy	Introduced the term "nature management"	1959
Strumilin	Model of optimal savings based on the perspective of efficient production in terms of imputed factor incomes, predicting increase in the optimal savings out of nature capital income	1962
Oldak	Environmental safety and economic development	1963
Khachaturov	Economics of environmental management covers two groups of problems: 1) how to use the resources necessary for production and consumption most efficiently, and 2) what are the most efficient methods of preventing or eliminating environmental pollution	1983
Balatskiy	Relations between the economy and quality of the environment	1984
Fedorenko	Agroecological and economic efficiency of land use management	1986
Danilov-Danilyan	The system of payment for negative impact on the environment (was introduced in the Russian Federation in 1991)	1991
Bobylev	The system of charged assessment of natural resources, and a unified system of assessment indicators and various nature-forming components	1995
Golub	Classifications of the economy of natural resources	1995
Gofman	Payments for natural resources, that is, for their consumption and for the right to use natural objects within a given territory	1998
Lemeshev	Optimization of nature management and environmental-oriented social development	2000
Ursul	Development of the noosphere science	2004
Lukyanchikov	Economic mechanism of nature management and environmental protection	2009
Potravny	Optimization of the use of natural resources	2017
Mirkin	Principal elements of the concept based on reducing the investment of anthropogenous energy into agroecosystems and stimulating biotic potential at all levels — from a specified plant and animal to the entire agroecosystem	2011
Kaverin	Ecological education for sustainable development	2014

Let's consider a simple model linking the sphere of production, the sphere of consumption and the environment through material and energy flows (Figure 6).

According to the scheme, raw materials (1, 2) are transubstantiated into consumer goods (5) and are disposed of as waste, which re-enters the environment (3, 4). In the sphere of consumption, goods ultimately turn into secondary waste, which is removed to the production sphere for further manufacture (6), and the remaining unused waste (3, 4) ends up in the environment. Waste that is not assimilated by the environment and cannot be recycled because the amount of recyclable waste exceeds the biosphere's regenerative capacity pose a threat to nature (see Figure 6).

To optimize the model, we need to cut flows 1, 2, 3, and 4. However, reducing flow 2 ends up with physical limits based on the law of conservation of mass, and the productive capabilities of the biosphere determines the maximum values of flows 1 and 3. The value of flow 6 reflects the consumer goods produced, but the greater the ratio of flow 6 to flows 3 and 4, the more efficiently natural resources are used; and the lower flow 4, the less pollution there is. If society needs a truly waste-free and closed production, then flows 2, 3, 4 should be absent. Optimal results, both from a technological and environmental point of view, are achieved when flows 2 and 3 do not exceed the biosphere's productive and regenerative capacities.



Note: 1 — renewable natural resources; 2 — non-renewable natural resources; 3 — non-recyclable waste assimilated by nature; 4 — non-recyclable waste accumulating in nature; 5 — consumer goods; 6 — recyclable waste.

Source: (Khoreva, 2014).

Figure 6. Connection between the spheres of production and consumption through material and energy flows

5. Environmental economics in the post-Soviet period

The development of the environmental economy in post-Soviet Russia was associated with the concept of sustainable development. During this period, a set of ideas about the peculiarities of the relationship between man and the biosphere was formed. Since the

publication of the UN document on sustainable development, Russia has followed the UN doctrines on greening sustainable growth and developing environmental economics. Some ideas represent the development of the Soviet "ekonomika prirodopol'zovaniya," i.e. nature management or economy of nature conservation.

Currently, the Russian Federation is implementing the Federal Law "On Environmental Protection" of January 10, 2002, which determines the priority of preserving the country's natural ecological systems. Krasovskaya analyzes Russian nature as a synthesis of geographical, socio-economic, geoecological, ethno-cultural and other knowledge about nature-human society system (Krasovskaya, 2013). Kaverin (2014) emphasizes that ecological education should be developed as a new model of civilization's transition towards sustainability (Kaverin & Masserov, 2014). Bobylev et al. (2015) describe transformation of Russian regions' economy into a green economy by investing in effectiveness of resources conservation and increasing energy efficiency (Bobylev et al., 2015). Mitrofanova and Starokozheva (2019) propose a number of ecological protection measures implemented in the Volgograd region (Mitrofanova & Starokozheva, 2019). Potravny et al. (2017) discuss the problem of the depletion of the Russian Federation's natural resources (Potravny et al., 2017; Gassiy & Potravny, 2017; Novoselov et al., 2017; Lukyanchikov, 2007). Bocharnikov (2019) argues that the ecological economy helps to solve the problems associated with the aggravation of contradictions between man and the biosphere. With its colossal development of productive forces, the 20th century became a critical starting point, beyond which the fate of humanity began to depend on the nature of the interaction between the environment and society (Bocharnikov, 2019).

The Russian-American project "Application of an interactive integrated assessment and modeling of a sustainable development strategy for the Arctic catchments (on the example of the Lake Imandra basin)" was carried out from 2002 to 2004. The project was based on Robert Costanza's work that played a significant role in the transition from the Soviet-style research methodology to international ecological economics. Costanza's works laid the foundations of environmental economics as a science, which nowadays has many adherents in Russia, united in the Russian Society for Ecological Economics (RSEE). More than 200 Russian scientists and public figures are currently members of the society, including well-known scientific authorities in the field of the economy of environmental management — Danilov-Danilyan, Bobylev, Golub, Gusev, and others (Kharitonova, 1982).

Nowadays, evaluation of ecosystem services began to develop again in Russia within the EU methodological framework. The Russian-German project "TEEB-Russia. Ecosystem Services Evaluation in Russia: First Steps" was initiated in 2013 by the Moscow Biodiversity Conservation Center (Bukvareva & Dmitry, 2016). In this report, the authors conclude that there is no statistics on ecosystem services (ES) in Russia, and consider steps to rebuild the ES system accounts.

The Russian Society of Ecological Economics has been operating in Russia since 1989. It organizes conferences in various cities. The first president of the Russian Ecological Society was Pavel Safonov. Today, the Society supports research in the field of ecological economics and methods for the development of nature protection.

Conclusion

In this study, the authors classify the development of the environmental economy from the time of the Russian Empire to the USSR and describe the changes in the model of the environmental economy throughout the century. The authors also identify the foremost researchers and the fundamental ideas concerning the economy and environmental protection.

Soviet scientists have always tried to draw the attention of the CPSU and the government to ecological problems, but often without success. For example, according to Gofman, from the 1960s to the 1990s, less than 2% of the USSR's GDP was spent on ecological conservation. However, experience shows that the financing was insufficient and required an increase in this share at least 4 times. Gofman emphasized that the CPSU officials rarely heeded to the opinion of the scientists. (Gofman, 1998). Nevertheless, economics of nature protection and resource conservation developed in the USSR within the framework of evaluating ecosystem services.

The authors can note the following limitations of the research:

(1) Some research works of the Soviet period were destroyed or removed from libraries to archives, where they were lost. Thus, it is hard to find complete information about the development of nature management in the USSR.

(2) Almost all the works were written in Russian without translation into another language.

The Soviet environmentally oriented economy had a unique character:

1. Scientists focused on protecting the agricultural sector (primarily, on the natural resources of the agricultural sector — land and water).

In the USSR, some scientists adhered to the idea that "economics of nature conservation is equal to fight against pollution" (Gofman, 1998; Fedorenko, 1977).

2. It was based on plans and not on the prevention of risks.

Despite various ministries and departments involved in the implementation of the state environmental policy, the existing regulatory framework and pollution control mechanisms, Russia is classified by the UN as one of the countries with the worst environmental conditions. According to various estimates, from 15 to 25% of the Russian Federation's territory is an ecological disaster zone. International experts believe that the measures implemented do not correspond to the real environmental damage and do not ensure ecological and economic rehabilitation of the territories.

In general, the authors can emphasize three characteristic moments in modern Russia:

- significant strengthening of the ecologically oriented legislative activity
- insufficient financing of environmental protection measures due to the severely underfunded economic situation in the country
- weakness of public authorities in implementing ecological standards.

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