Environmentally Sustainable Management of Rice Cultivating Zones in Ukraine

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Abstract More than half the world's population depends on rice, which is grown on nearly 140–150 million ha of land for a global production of more than 520 million tons annually. As for Ukraine, it is quite new introduced crop which has great potential in Southern Ukraine. But cultivating rice in Danube and Dnepr, lots of problems remain unresolved: the danger of secondary soil salinization, the deficit of irrigation water, there is no drainage water utilization system, water and wind erosion bring significant losses, imperfect technologies of crop protection, there still might occur significant technological discharges containing residues of herbicides, pesticides, and mineral fertilizers into the basins of the Black and Azov Seas. In the article below, we focus on capabilities that maintain soil fertility, preserve or even improve the rice-growing environment in Ukraine, and provide possible opportunities for sustainable land usage beyond rice monoculture in Danube and Dnepr deltas to avoid some adverse effects listed above.

Keywords Paddy field · Irrigation system · Ukraine · Rice cultivating Environment

1 Introduction

It is well known that rice (*Oryza sativa L.*) fields are integral part of the landscape throughout most of the subtropics and tropics. Rice is a major crop that is planted in the most diverse environmental conditions; from sea level, to 3000 m altitude in the Himalayans, from 35° S in Australia to 49° N in the Czech Republic. Temperatures and day lengths are therefore quite diverse in the rice-growing areas. Rice is also grown under different water conditions, from mesoxeric conditions to deepwater reaching up to 5 m [1–3].

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In the world, Ukraine is always associated with large cereal fields and usually is mentioned like European breadbasket. Nowadays, Ukraine is one of the largest producers of corn, wheat, barley, and sunflower seeds not only in Europe but in the world too [4, 5]. Despite the fact that Ukraine is located in temporary climate zone, it has significant areas with rice exclusively japonica type (*sino-japonica*).

In the past when Ukraine was the part of the Russian Empire and then the USSR, rice appeared in our country only in the beginning of the twentieth century. So, it was unrepresentative cereal as distinct from wheat, rye, and barley. At first in the USSR, rice had been grown in the Middle Asia and the South Caucasus areas but with developing of cotton production in those regions, rice fields curtailed drastically. By the fact that rice needs much water then cotton and water is really limiting factor in this region. That is why weather conditions and absoluteness of water resources allowed transferring rice plantings to the southern part of Ukraine, mainly to Danube and Dnepr deltas [6].

2 Engineering Nonconformance of Irrigation Systems

Rice cultivation systems can be considered natural-engineering or natural-anthropogenic systems as they consist of two components: (1) natural, that is determined by natural factors (climate, soil, groundwater, flora, microorganisms, etc.) and (2) anthropogenic, which is attributable to human economic activities (construction of channels, roads, and field levees; planning of paddy fields arrangement that involve some tilth-top soil hauling; fertilizer and herbicides treatment, and most crucially supply of water for irrigation entailing the change of original air and water regime of the particular territory) [7, 8]. Talking about former USSR countries, it is obvious that the design of rice irrigation system did not consider the environmental conditions formed on the basis of natural steppe ecosystems exposed to insufficient atmospheric moistening, automorphic, and semi-hydrogenic soil regime and is dramatically different compared to the growing conditions of the rice culture, requiring long-term paddy field flooding. In view of this, paddy fields should be considered rather temporarily marshy than steppe ecosystems.

At the time of designing the rice cultivation systems in 60–70th of the XX century, there was not enough knowledge and experience in Ukraine to make correct estimates of the influence paddy culture would produce on the environment. It was generally believed that washing out salts would be enough to increase soil fertility; however, the influence of rice irrigation systems on the state of the agricultural landscape of the Black Sea region appeared to be much more complicated [9].

On the territory of Ukraine, most of the irrigation channels feeding paddy fields were constructed just in the ground bed, only some being covered with concrete slabs and only two constructed with the use of concrete ducts. The channels of drainage-waste system were totally built in the ground bed; some channels being

strengthened with reinforced concrete slabs. Most of the plots are of the Krasnodar type and consist of paddy fields of rectangular shape. That was a reason which caused appearance and then establishing of different sedge species and some other native wetland plants through the rice cultivating areas. The paddy fields are arranged across the plot and extend from the irrigator to the spillover. Water supply of every paddy field is supported with the plot irrigation channel, whereas water removal is conducted via the plot outlet channel [10–12].

It is necessary to notice that the strategies for mitigating salinity problems in rice production include both the development of management options and the genetic improvement of salinity tolerance in current cultivars. Although the use of some management options can ameliorate yield reduction under salinity stress, their implementation is often limited because of cost and availability of good quality water resources [11, 13, 14]. Therefore, the need for genetic improvement of salt tolerance is great and is expected to increase dramatically in the nearest future.

The existing schemes used for water management of paddy fields are characterized by huge water loses due to technical imperfections of their constructions, absence of proper irrigation rotation, poor rate of drainage/wastewater reuse, the presence of technically unsound and unproductive water removal. All these result in the increase of irrigation rate up to 25–30 thousand m^3/ha while for the most paddy culture lands of the south of Ukraine, characterized by heavy and mediate soil texture and the groundwater level of 1–3 m, the net irrigation rate ranges from 14 thousand m^3/ha to 20 thousand m^3/ha [15].

The Black Sea and Sivash regions favoring agroclimatic conditions for rice growing exist over approximately 1 million ha of land of which around 200 thousand ha are low-output soils. The area which is technically suitable for paddy culture in Ukraine comprises more than 300 thousand ha (Fig. 1), of which in Kherson Oblast—172, in Odessa Oblast—37, in Mykolaiv Oblast—34, in Zaporizhzhya Oblast—65, in Zakarpattia Oblast—12 thousand ha [16].

Growing rice in Ukraine and some other Eastern Europe countries is carried out exclusively with the use of rice irrigation systems which represent complex irrigation utilities designed for supplying water in the field, providing and maintaining the necessary level of water in it throughout the vegetation season, as well as quick water removal from the paddy fields and fall in groundwater level for the rice harvesting period and in winter. In the late 80s, the development of irrigation and drainage in the southern region of Ukraine resulted in the increase of drainage and wastewater outlet to about 2 km^3, and the application of chemical crop-protecting agents, chemical ameliorants, and mineral fertilizers created the severe environmental conditions in the Black and Azov Seas basins. The most unfavorable influence was due to the rice irrigation systems. For example, about 0.65 million tones or 37% of the 2 million tones drainage and wastewater outlet discharged each day to the sea basins was due to the rice irrigation systems, whereas they comprise only 4% of the irrigated land of the south of Ukraine. Paddy culture area of Ukraine spreads over the territory encompassing a considerable amount of recreational resources. In the late 80s of the XX century, in the southern region of Ukraine, there arose significant contradictions: either rice or recreation area. It has brought about

Fig. 1 Rice cultivating areas in Ukraine (marked in green)

hasty decisions concerning prohibition of paddy culture development. Rice has been declared to be the death-threatening product and rice grower to be the concealers of a crime [17–19].

Significant water discharges from rice irrigation systems as well as industrial discharges and wastewater negatively affected the hydrological and ecological regime of the territory and the marine area of the Black and Azov Seas. There is a loss of healing properties of the sea water and a sharp decrease in its mineralization in the coastal zone. In the early 90s of the XX century, biological productivity as well as opportunities for the self-clarification of the Black Sea decreased significantly, and consequently, a significant part of the Black and Azov Seas coasts rendered unsuitable for recreational purposes. Although not all the ecological problems of that time were associated with paddy culture industry development, most of those were attributed to this industry. In this connection "green" environmental groups stroke the active campaign against paddy culture industry which came to tough contradictions between the public and rice growers. The situation was complicated by the mass media, who published articles about the negative impact of the rice industry on the ecological state of the southern region of Ukraine. Owing to this situation since the 90s of the XX century, the area of rice systems began to decline and rice was gradually removed from crop rotation on the rice-growing area of Ukraine. However, these measures did not significantly improve the environmental situation in the region. Truth to be told the same situation was observed in some other countries of the Black Sea basin [20–22].

Another reason of reducing rice paddy areas in Ukraine is the shortage of warmth and sunny days. Temperature affects not only the growth but also the development of the rice plant. Usually effective heat sum has been within 3000–3600 °C, and frost-free period consists of 155–210 days. Accumulated, it allows growing only early ripening and some mid-duration rice varieties. But in some seasons with poor weather conditions, rice productivity in Ukraine was above 3 tones per ha and even less (generally the rice yield is about 5.0–5.2 tones per hectare). Low temperature during the reproductive and ripening phase of the rice plant usually results in high shattering percentage of the grains in several of the high-yielding modern rice varieties [23–25].

3 Regional Particularities

Each region is characterized by its specific environmental conditions; that means, each region represents the super complicated ecological system that includes such subsystems as nature, society, and production. Being interconnected and interdependent, they should develop in such a way that would support their complemental coexistence on the basis of conflict-free usage of natural resources potential. The point at issue is about providing the adequacy of interests for preservation of the environment, solution of contradictions between development courses of different branches of economy in the region, and timely addressing conflicts of interests in the field of natural resources management [26].

The natural resources potential of the Black Sea region promotes the development of various economic sectors of the region—industry, agrarian sector including paddy culture, and recreational and touristic complex. The agrarian potential of the paddy culture region of Ukraine is quite significant due to its land and aquatic resources, natural and climatic conditions, etc. The availability of natural resources by itself does not support, but in many cases rather impedes economic development, stimulating a rent-seeking economic behavior. On the contrary, the regions with poor natural and climatic conditions demonstrate activity and inventive power concerning implementation of sustainable technology and innovative solutions. The agrarian sector of the economy is one of the most powerful business entities in the Black Sea region. It is represented by the intensive irrigation agriculture over the area of more than 1 million ha in Ukraine only [27, 28].

There were lots of reasons for contradiction. Growing crops, including rice, with intensive technologies, application of significant amounts of herbicides, pesticides, and fertilizers, usage of unrestricted volumes of water for irrigation, as in the Soviet era its cost was negligibly low and was almost completely offset by the state, have led to pollution with pesticides and mineral fertilizers not only in the rivers of the Black Sea region of Ukraine, but also in the water of the Black and Azov Seas. Application of significant amounts of herbicides, pesticides, and fertilizers was required not only for paddy culture; they were in use also for grain and vegetable rotation, as well as for grape groves. Therefore, one has no reasons to charge the

paddy culture industry with all the existing ecological problems. For example, the state of the Azov Sea is largely dependent on the environmental safety of technologies used for growing of crops, including rice, in a neighboring country, Russia; hence, the water from its southern agricultural areas is discharged into the Azov Sea. Only decades after that, the ecologists started their researches and found out the enormous influence of mentioned substances on fish culture, wild marsh plants, and biodiversity overall [29–32].

Rice is one of the few crops, the intensive production of which requires the use of significant amounts of irrigation water, doses of mineral fertilizers and chemical agents for the protection of crops from pests, diseases, and weeds. Application of significant amounts of pesticides and herbicides, the unreasonable irrigation schedule conditioned the pollution of receiving basins with chemical crop-protecting agents and water conversion everywhere [33–35]. There were the reasons of rice cultivating areas and gross output negative dynamics (Fig. 2, as per Governmental statistics).

In recent days, one of the reasons of reducing rice areas in Ukraine is the problem of weed control in rice crop rotation, especially ruderal rice with colored grain, which appeared more widely in Eastern and Southern Europe [36]. As per systematic attitude, it is the same species that cultivated rice *Oryza sativa L.* All of its forms have negative characteristics such as lodging, fall of grain, poor grain quality, susceptibility to main diseases. On the other hand, list of characteristics allows ruderal rice to be more competitive than cultivated rice. For example, longer seeds dormancy period, stretched germinating and blowing period, rapid growing, vigor of shoot growth. Blotchy ripening and ability to fall of grain immediately after

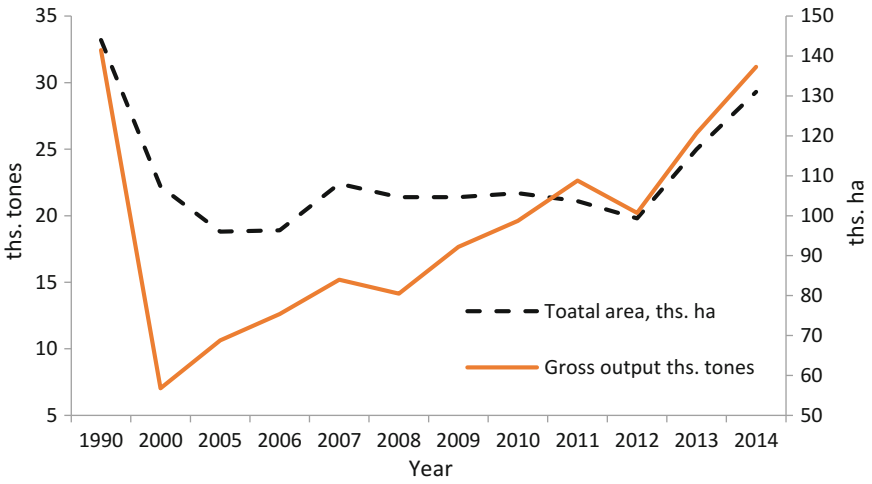

Fig. 2 Dynamics of rice gross output and cultivating area in Ukraine during period 1990–2014

ripening accumulate abnormal stocks of ruderal rice seeds in the field [37–42]. All of mentioned above produce difficulties in rice growing, even though totally infested fields usually removed from rice crop rotation for at least 2–3 years.

This situation is not the isolated case of the late 80s of the XX century; it also emerges in the 60s of the same century. It is noted by experts in connection with unjustified ecologically dangerous technologies, which at that time are already used in irrigation farming and, especially, in the flooded paddy fields. The huge volumes of the freshwater with dissolved chemical agents and fertilizers are discharged into the bays and basins of the Black and Azov Seas. In the 70s of the last century, coastal waters of the southern seas were unacceptably desalted so that the water salt content in the Dzharylhats'ka Gulf in summer reached only 1–2 g/L compared to the natural level of 16–18 g/L [43].

4 Legislation Regulatory

In the explanatory note (1967) to the project of the overall irrigation in the south of Ukraine submitted by the research institute "Ukrdniprovodhosp," scientists and designing engineers forecasted the next scenario: "in view of the continuous rice cultivation in the coastal zone radical measures will be required in order to protect large settlements from flooding which will include liquidation of the resort zone along the Black Sea coast and protection of 32 settlements in the rice cultivation zone …." This forecast has come true to some extent, although such a critical situation could be avoided had these scientists and designing engineers scheduled in their projects some measures for protection of soil fertility, water resources, and environment. Though they have limited themselves to mere verbal warnings, not providing any pro-active approach. And nowadays we need to eliminate these mistakes, deal with ecological challenges, maintain the paddy culture, and provide protection and sustainability of recreational resources of the south region. In connection with the complicated ecological situation in the early 80s in the south region of Ukraine, the Council of Ministers of the USSR, by Resolution No. 166 from 09.04.1976 "On measures to prevent pollution of the basins of the Black and Azov Seas" (paragraph 8) to the Ministry of Agriculture and the Ministry of Water Resources, the Southern Department of VASGNIL was commissioned to conduct the necessary studies and to develop, by 1980, measures aimed at improvement of the environmental status of the south region of Ukraine and abandoning the discharge of water containing pesticides and their compounds from rice irrigation systems into the gulfs and limans of the Black and Azov Seas. Within the scope of these executive directives between 1976 and 1986, Ministry of Water Resources of Ukraine has accomplished reconstruction of 40% of rice irrigation systems. The reconstruction was aimed at the increase of the technical level of the RISs though it did not address the main issues—water and land resources conservation and environment protection. And in the early 90s with the break-up of the Soviet Union, the reconstruction was completely stopped [44, 45].

According to the Water Codex of Ukraine (1995), Chap. 18, "Use of water resources lands. Water protection zones and sanitary protection zones" along the seas and around the sea bays and gulfs "… it is allocated a protected shoreline belt with width of not less than two kilometers from the edge of water." Protected shoreline belts are nature reserves of limited economic activity. Besides, "protected shoreline belt along the seas and around the sea bays and gulfs is a part of the sea sanitary protection zone and can be used only for the construction of sanatoria and other recreational compounds provided with centralized water supply and canalization." According to Art. 93 (Chap. 18) of the aforementioned Water Codex of Ukraine "… in order to protect water objects in the areas of water abstraction for therapeutic and health-promoting needs, it is necessary to establish sanitary protection zones with subdivision into zones of special regime."

Being under the regulation of such Laws of Ukraine as "On the National Program for the Formation of the National Ecological Network of Ukraine for 2000–2020," "On the Nature Reserve Fund of Ukraine" (2000), "On the environment protection" (1996), and the "Water Code of Ukraine" (1995), the Black Sea region territories, including paddy rice culture areas of Ukraine, are provided with four levels of protection from the negative impact of nature management, nevertheless today we recognize these territories as being in the state of ecological depression of varying degrees and also consider them as zone of potential ecological and economic risks. One can confidently assert that the existing legislative and regulatory framework is almost never implemented or fulfilled. This is the reason for these territories being in the state of ecological depression.

The Resolution of the Cabinet of Ministers of Ukraine No. 703 dd. May 18, 1998 "On the sanitary protection of the Skadovsk Medical Zone within the Skadovsky District" strictly prohibits the use of crops growing technologies (e.g., for rice, vegetables, grapes) which involve the use of chemical crop-protecting agents. On the other hand, it is found that this district is more polluted with herbicides, including glyphosate and piretroids compare with neighbor districts [46].

In accordance with the existing legislative and regulatory framework, the width of the sanitary protection zone is 2 km from the shoreline of the Black and Azov Seas, and using this zone imposes stringent requirements on the rice growers and other agricultural producers concerning application of crop cultivation technologies.

Socioeconomic development of the Black Sea region of Ukraine and the special aspects of environmental safety policy formation in the region should take into account the peculiarities of the natural ecological systems and set out effective environment mitigation actions.

The proper quality of the environment should be considered not only as the prerequisite program but also as the result of the region development strategy implementation. Based on this methodological approach, there arise two fundamental requirements: firstly, it is necessary to provide for simultaneous handling of all the socioeconomic, environmental, and economic issues, as well as problems related to the usage of natural resources potential, economic development, and environmental quality management. Secondary, it is necessary to carry out a

comprehensive assessment of the programs and projects of the region development, considering the possible ecological and social consequences, including those conferring adverse effect on ecological and economic systems of different development level, from the local to the macroeconomic.

The transition of the region to the environmentally friendly level of development involves the proper balancing of issues connected to the social development, raising the well-being of the people and the economic development of the region on the one hand and natural resources potential on the other hand. When designing policies of the environmentally balanced development of the region, it is necessary to rely on the acceptable demographical, ecological, production, and technical and process design indices.

The analysis of the usage pattern of the natural resources being the most important on the territory of the region (land, water, recreational, and others) has shown that the natural resources potential of the region is the important prerequisite for the socioeconomic development, contributing to the implementation of the economic branches transformation in the region [22].

The study of nature management patterns in the region shows that almost every branch in the region is characterized by an insufficient application of environmentally friendly and resource-saving technologies, the low level of mechanization and automation of production processes, the prevalence of technologies oriented on the intensive use of natural resources, and running of production processes with low coefficient of resource productivity. This situation results in the unjustified large losses of natural resources. The main causes of this situation include high energy intensity of the economy and a significant level of environmental pollution, the impact of extensive agricultural production on the state of ecological and economic systems, the shortage of water resources in a significant part of the country, as well as insufficient level of development of environmental institutions [47].

Adopted in 2003, the Law of Ukraine "On the Fundamentals of National Security of Ukraine" broadly interprets the concept of national security and draws attention to such environmental problems as industrial pollution and the generation of waste, deterioration of water quality, inappropriate use of natural resources, adverse effects of past military activities, as well as environmental hazards of existing obsolete technologies.

The list of external security hazards includes global environmental changes and the import of potentially harmful technologies, and specifically genetically modified organisms. The law also addresses cross-border environmental problems, including issues concerning co-management of cross-border basins and problems related to pollution of the Black and Azov Seas.

5 Short-Term Outlook

To our opinion, the formation of environmentally friendly economic policy for the Black Sea region of Ukraine should involve such main directions as:

- indication of the natural resources potential features and advantages of the region, which distinguish it from the other regions and determine possible directions for development;
- analysis of the natural resources potential status and identification of disadvantages inherent to the region development with a view to their subsequent elimination;
- designing of a strategic plan for the use, restoration, and protection of natural resources on the basis of the top-priority goals of the region's development;
- synchronous reorganization of the institutional management of the region's economy, which involves the creation of institutions oriented toward a market economy, improvement of the regulatory framework concerning use, conservation and reproduction of natural resources. The institutional aspects of the nature management envisage the ecological orientation of the bio-socioeconomic system functioning in the region.

Such aspects of scientific and technological progress as environment protection, environment safety, and resource saving should be prioritized in all areas of the region's economy and used as a guideline for designing of investment and innovation policies of the region. These directions should be considered as one of the top-priority goals on the path to the ecologically balanced nature management, which will lead to overcoming of the resource-ecological crisis and will contribute to the environment improvement.

The introduction of environmentally friendly policies in the region will create conditions for optimal and balanced functioning of the ecology-economic system, which will allow:

- to balance the economic structure of the region;
- to ensure nature management with respect to ecological principles and preservation of the natural environment;
- to form a modern market of competitive agricultural products together with recreational and tourist services;
- to ensure a high social level and increase of well-being of the population in the region;
- to reduce the level of depression of the region and create conditions for non-conflict multidisciplinary use of natural resources potential of the region.

Considering the Black Sea region depression status and the ongoing conflicts of interests arising from multisectoral usage of its main natural resources, as well as the fact that the territory of the region belongs to the zone of potential ecological and economic risk, it is quite logical to conclude that at this stage of socioeconomic development of the region and the implementation of market transformations, there is an urgent need for a fundamentally new sustainable macroeconomic and microeconomic policy. This policy should determine the real courses, methods, means, and effective mechanisms for the transition of the eco-economic or bio-socioeconomic system "economy-society-ecology" to the model of environmentally sustainable development both at the state and regional and local levels.

The implementation of the principles of environmentally sustainable development is particularly important at the regional and local levels, since this is where the state authorities, the public and society understand the social, economic, and resource-ecological problems, see concrete ways and possibilities for their purposeful solution in the best possible way. Designing the principles of environmentally sustainable development requires separate consideration of the characteristics of each region and each separate territory. Currently, each region of Ukraine has its specific territorial production and socio-ecological systems, which are characterized by a certain composition and structure as well as quite large differences.

The model for the environmentally sustainable nature management resides on the concept that economic models of development are closely interrelated with macroeconomic policies and is characterized by criteria defined below:

- the level of social relations development concerning development of their environmental aspect;
- limited natural resources;
- the level of scientific and technological development and the possibility of technology transfer.

In addition, there is an urgent need for detailed assessment the agrarian sector of the economy as for its trends and impact it impose on the ecological state of the recreational resources of the region and the recreation area itself. The results of such an assessment could be further used to increase the effectiveness of activities aimed primarily at resolving contradictions and achieving a balance of interests between different sectors of the economy, developing in the region.

In the context of this study, it is important to address the issue concerning the development of the environmentally sustainable nature management concept for the zones, which are zones polyfunctional purpose and at the same time zones of potential ecological and economic risks (for example, the zone of paddy culture in Ukraine). The dominant idea of the concept is the optimization of nature management within the existing ecological potential and maintaining the balance of the eco-economic system of the region. The concept of environmentally sustainable nature management, developed by the authors of this research, in the context of government-wide and national interests can serve as a powerful tool for effective management decisions on the implementation of environmental policy in general, the identification of priority vectors for the development of territories, taking into account models of their multifunctional use and the balance of interests regarding the optimality of environmental decisions.

From the foregoing, it follows that further economic growth in the regional context and the exit from the ecological and economic crisis is possible only under the following conditions:

- elimination of existing developmental disproportions of the economic-industrial complex of the region;
- development of measures and mechanisms for attracting funds from local authorities to combat the flooding and solving social problems, arising as a result of flooding;
- rational usage of unique recreational potential in the context of environmentally sustainable nature management model of the region;
- design of an effective regional innovation policy, based on the latest scientific and technical achievements;
- development of the model for the investment and innovative development of the region, which will provide conditions for the transformation of scientific research results into resource-saving, science-intensive, low-waste and non-waste technologies, and competitive goods and services;
- dedicated improvement of the financial and credit mechanism of investment and innovative development via transition to program-targeted development management methods that involve the definition of specific tasks, specific research objects, and due dates of research work with the obligatory consideration of global development processes.

In the existing competitive business environment development of an effective ecological-economic nature management demand transition to the business mechanism of state and regional management. This can be achieved through the formation of an effective legislative environment, the use of effective economic instruments, the formation of investment and innovation policies, as well as the executive mechanisms for ensuring the preservation of the environment and socio-economic development of the region.

The negative impact of paddy culture on the environment is predominantly attributable to the discharges of drainage and wastewater outlet containing residues of pesticides, herbicides, and mineral fertilizers beyond the limits of irrigation systems. Nowadays, there is a tendency for decrease of rice yield and production profitability, and the ecological status of the paddy culture and the adjoining offshore zones has considerably deteriorated. The time is ripe for radical ecological, agricultural, and economic measures.

In the mid-80s of the twentieth century, in Ukraine was launched the process of rice irrigation systems reconstruction. There were made certain steps toward solving the problems concerning the ecological status of both rice irrigation systems and the Black Sea and Azov Seas basins in general. However, the reconstruction, which took the form of partial improvement of rice irrigation systems (channels lining, improvement of hydro-technical utilities, arrangement of closed collector-drainage network, improvement of rice cultivation technology, use of drainage and wastewater for return flow irrigation), did not radically reduce the sharpness of environmental problems in the southern region of Ukraine.

In recent years, the Ukrainian water industry is setting its sights on transition to ecologically sound agricultural production, obtaining stable yields of environmentally safe agricultural products, reduction of electricity costs, saving of water

and land resources and preservation of soil fertility. This course is also accompanied with improvement of quality and reliability of scientific research results, as well as the introduction of new rice production technologies and new generations of rice irrigation systems.

New technically upgraded rice irrigation systems should meet the following requirements:

- be environmentally friendly;
- to ensure electricity conservation, as well as water and land resources preservation and reproduction;
- to maintain the hydrogeological and reclamation state of irrigated land in accordance with paddy culture requirements;
- to ensure the preservation of soil fertility;
- to prevent pollution of agricultural and adjacent territories and marine areas;
- to promote the introduction of environmentally friendly technologies with reduced application of herbicides for the cultivation of rice and related crops.

6 Conclusions

The model of rational nature management in the paddy culture area of Ukraine should be based on the concept of sustainable nature management and provide for integrated development of the rice industry and recreational complex with simultaneous preservation of natural resources potential and environment of the region:

– provide the perspective plan for development of the paddy culture branch on the basis of reconstruction of existing rice irrigation systems into closed-type paddy field return flow irrigation systems and the introduction of new environmentally friendly technologies for the cultivation of rice and related crops;
– provide the road map for the rational use of recreational natural resources of the Black and Azov Seas, establishment of a recreational complex and appropriate infrastructure, taking into account the requirements of sustainable nature management.

Realization of these requirements is possible only with consideration of all the interrelations and factors of mutual influence inherent to components of natural resources potential of the paddy culture area, which can be used now and in the future for improvement of the population living conditions, ecological well-being, and integrated development of the region.

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