CURRENT STATE OF LAND USE AND PROSPECT OF ITS AGROFORESTAL OPTIMIZATION IN THE CASPIAN REGION OF RUSSIA AND KAZAKHSTAN

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Abstract

The current state was studied and main trends of land use development under the influence of changing climate and anthropogenous influence were revealed. The spatial structure, direction and features of regional development of agricultural production in new market conditions of Russia and Kazakhstan was estimated. Creation of agroforestal complexes which have to become a necessary component when forming the profitable country farms located discretely in primordially treeless territories and applying resource-saving technologies was offered for its optimization.

Key words: *land use, arid territories, optimization, agroforestry, afforestations, adaptive environmental management, semi-desert*

1. INTRODUCTION

The development of agricultural complex in Russia and Kazakhstan changed in connection with transition of productions to market relationship after the USSR collapse from 1990th years. Now the use of small-contoured allotments starts by country farms and small cooperatives with reorganization of agricultural production methods. Marauding way of land use promoting anthropogenous desertification prevails in many of these enterprises. At the present stage there are not numerous works which describe these tendencies only from legal and economic point of view, however ecological consequences of such reorganization were still estimated insufficiently (Rees, 2003; Milenov et al., 2014). Meanwhile, there is a foreign experience of so-called farm tenor of life as in arid (Australia, Africa), and semi-arid and humid conditions (Europe, North America) (Woodhouse, 2012: Jellinek et al., 2013; Alonso, Northcote, 2013; Chen et al., 2014). The majority of economic entities poorly represents potential possibility of different types of dry steppe and semidesertic soils to the reproduction of fodder resources (hay, grain) and to the pasture therefore they use sites with maximum loading without recovery actions that leads to the pastures digression, deterioration of agricultural fields fertility, cutting down, drying and disintegration of afforestations belonging to them. Strengthening of aridization (climate dryness) from the middle of the 1990th years, causing climatogenic change of fodder and water resources of the region makes impact on the functioning of vegetable ecosystems in West Kazakhstan and semidesertic Zavolzhye of Russia.

Adaptive methods of forest-agricultural environmental management based on inexhaustible technologies (Concept …, 1996) which component have to be durable forest crops are being developed at the present stage. Such approach in arid regions will be coordinated with the concept of natural ecosystems sustainable development (Enters, Hagmann, 1996; De Graaf at al., 1996). The main objective of agroforestry works in steppe, dry steppe and semidesertic regions which are primordially occupied with grassy vegetation is the increase of farmlands efficiency and creation of comfortable living conditions of population. Extensive scientific experience of forest crops cultivation of various functional purposes was saved up in the world. Numerous ways of creation and increase of forest crops stability were offered (Agrolesomelioration, 1974; Tschinkel, 1987; Young, 1988; Owino, 1996; Singh at al., 1998). Features of forest plantings functioning in arid regions of Russia were considered and methods of creation durable agroforestry systems on complex soils of Northern Prikaspiya were offered on the basis of own 40 years' researches (Sapanov, 2003; Sapanov et al., 2005). Methods of forest improvement mapping of arid territories and phytoecological assessment of

unproductive lands for the purpose of their adaptive transformation into steady agroforest landscapes were developed (Kulik, 2004). Monitoring of soils fertility and analysis of land structure use in West Kazakhstan region was carried out. The assessment of qualitative state and characteristic of land grounds efficiency were carried out. Recommendations for the transition to landscape ecologically land management were developed (Akhmedenov, 2010).

Foreign scientists also actively research environmental management in arid ecosystems. Works of Chinese scientists (Xue at al., 2015) are devoted to the problem of fragile arid territories study on example of Mínqín xiàn district. The results of land use ways adaptation in a desert zone of northern part of Negev desert were described in the works of Israeli scientists (Wong at al., 2015) and reaction of ecosystem to the land use changes as well. Using remote-sensing instruments, the dynamics of vegetable cover change under anthropogenous influence in droughty agricultural ecosystems in northwest Mexico (Romo-Leon at al., 2014) was revealed. Reforestation model in semi-arid zones of southeast Spain (Berenguer, 2013) was offered.

The idea of this work consists in the study of transformation of grassy and forest ecosystems of natural and artificial origin in conditions of dry steppe and semi-desert of West Kazakhstan under the influence of modern climate change and market reorganization of land use ways for the development of offers on its optimization. Unification of Kazakhstan and Russian scientists' efforts for the fight against desertification is very actual for the search of modern optimum solutions of steady environmental management problem. Researches on this project correspond to the priorities of Convention on biological diversity, Framework convention of the UN on climate change, Convention of the UN on fight against desertification and Programs for fight against desertification in the Republic of Kazakhstan for 2005-2015, State program in the field of environmental protection "Zhasyl damu" and other branch programs.

1.1 Purpose and problems of the research

The work purpose - identification of steady functioning mechanisms of ecosystems of natural and artificial origins (virgin lands under pastures and haymakings, agricultural fields, agroforestal systems and massive afforestations) taking into account different intensity of their economic use and climate change. The main objectives included:

1) Study of current state and identification of main trends of vegetable ecosystems (digression, demutation, penetration of invasion types, natural successions) development under the influence of changing climate and anthropogenous influence, including virgin sites (pastures and haymakings), forest (inundated and agroforest systems) and agricultural fields (both used and waste).

2) The analysis of statistical data in government bodies in the ways and volumes of agricultural production in West Kazakhstan in time and space for identification of objective modern situation in the development of productive forces.

3) Assessment of spatial structure, direction and speed of regional development of agricultural production and identification of optimum model of sustainable development of droughty territories with functionally significant, low-cost and ecological inexhaustible ways of managing on fertile and poor types of soils.

1.2 Objects and methods of researches

The works were carried out on key sites, ecologically representative for the most part of Caspian Depression to the interfluve area of the Volga and the Ural. The territory of Dzhanybek Research Station located on drainless semidesertic clay plain of the interfluve area of the Volga and the Ural with complex vegetable and soil cover was chosen as one of the main sites. Distinctive feature of permanent study area is that it is located on both sides of Kazakhstan-Russian border and is used by the research associates of both states. In other words, the works were carried out in uniform scientific information space with the involvement of Russian research associates working here. Other key sites included main ecosystems of dry steppe and semi-desert: reserved, agricultural fields (used and fallow), pastures of different extent of degradation, afforestation in the Ural River's bottom-land, steady and drying-out windbreak and roadside fields of different design. The subject of our researches

is an identification of low-studied trends, speeds and reversibility of serai processes of vegetable communities of natural and artificial origin. The main method of researches was multiple-factor analysis of functioning and adaptation mechanisms of separate types and ecosystems in general to the arising environment fluctuations. The results received at key sites were used as well as the data of unique long (more than 60 years) climate monitoring, soil and hydrological conditions and state of grassy and forest ecosystems on Dzhanybek Research Station area. Well-known methods in ecology, climatology, geobotany, soil science, hydrology, etc. were used in the work. Analytical works were carried out according to the state standard specifications and standard techniques. WKATU laboratory base as well as chemical laboratory of Dzhanybek Research Station was used. Obtained data were processed with application of modern methods of GIS-technologies and statistics for obtaining reliable results.

2. NATURAL FEATURES OF THE REGION

The climate of researches area is characterized by the pronounced continentality and dryness that is peculiar to semi-deserts of subboreal belt. First of all, it is shown in repeated excess of evaporability (about 1000 mm) over rainfall (about 300 mm) and instability of atmospheric moistening is a distinctive feature of weather conditions. Thus, dry and damp periods alternate not chaotically, and unite in dry and damp long-term cycles. It is sometimes fixed $+42^0$C in summer, in winter – (-38^0C). Low-snow winters and dry winds are frequent. Snow cover keeps usually from November to March, average power seldom exceeds 10-20 cm, in snow winters it reaches 40 cm (Biogeocenotic bases …, 1974).

The area belongs to lake inundable depression, northwest drainless loamy Dzhanybeksky semidesertic plain (Doskach, 1979) and is dated for waterless and unexercised part of the Volga-Ural interfluve area. Its area reaches nearly 3 million hectares. Loams are generally uniform in particle size distribution and concern to average and heavy silty large-dusty loams. Its plains with expressed meso- and microrelief are the feature of the considered region as well.

Negative forms of mesorelief are presented by narrow valleys (from 1 to 100 hectares) with dark-colored black earth or meadow-brown soils and estuaries (up to 1000 hectares) with solodized soils and soloths occuping to 10–15% (Rode, Pol'skii, 1961). Narrow valleys represent mesorelief decreases of roundish or slightly extended form with cutting depth to 1 m and flattened bottom. Soil ground waters lying at the depth of 5-6 m are replenished with thawed snow once per 5-8 years. Lenses of fresh ground waters of hydrocarbonate-calcium structure with mineralization about 1 g/l are formed for this reason under meadow-brown soils of narrow valleys.

Other part of the territory represents inter-narrow valley plain with the developed microrelief which basic elements are microdepressions, microslopes and microhighs. Microdepressions with meadow-chesnut soils occupy up to 25% of inter-narrow valley plain space. The same space is occupied by microslopes with light-chesnut soils bordering microdepressions with narrow strips of 1-3 m wide. The main background of inter-narrow valley plain (about 50% of total area) is formed by microhighs with saline solonetzic soils. Microdepressions are the centers of soils desalting on loamy soils of Caspian Sea region and promote creation of special type of landscape here - spotty or complex semi-desert representing specific feature of this ecotone, transitional zone of the southeast of East European Plain (Nikolaev et al., 1997; Zolotokrylin, Titkova, 2004).

3. RESULTS AND DISCUSSION

Semidesertic region of Northern Caspian Sea region in the Volga and the Ural interfluve area including 2.9 mln ha of natural complexes with salted saline solonetzic soils and solonetzic light-brown soils represents difficult object for economic use. For example, virgin grassy sites at repasture of domestic animals degrade easily and are long restored, and the crop on agricultural fields suffers from the general deficiency of moisture, frequent droughts and dry winds. Therefore, this territory

belongs to the risky agriculture zone. Besides, general climate change leaves an imprint on vegetation condition (Sizemskaya, Sapanov, 2010).

Desertification: climatogenic and anthropogenous - which has essential scales is a major factor of degradation of vegetable ecosystems in the studied region of semi-desert of Northern Caspian Sea region. So, for example, the total area subject to desertification occupies about 1220000 km2 in the Russian Federation only. This territory is located in three subbands: arid - 70000 km2, semi-arid - 320000 km2 and dry subhumid - 830000 km2 (Vinogradov, 1993).

The main processes characterizing desertification manifestation are: pasturable digression, deterioration of pasturable vegetation structure; decline of pastures efficiency, replacement of nutritious forages with low-edible and inedible plants; decline of soils fertility, including dehumification as a result of unreasonable plowing of unsuitable soils; secondary salinization of soils as a result of unreasonable and wrong irrigation of soils, in particular without necessary drainage; deflation of light soils, development of dust storms; water erosion of heavy soils, development of ravines, superficial washout of soils; increase of drift sand area; exhaustion, pollution and salinization of local waters and siccation of fresh water sources; decline of biological diversity; cutting down and oppression of wind and water protective wood and shrubby vegetation; increase of climate aridity, increase of frequency and duration of droughts; flooding and water-logging, salinization and bogging of soils as a result of unreasonable and inefficient water construction in arid areas; technogenic desertification because of heavy transport, drilling activity and earthwork, industrial and water construction; industrial pollution connected with chemical productions, mining.

For example, now there are 50–70% of degrading arid territories in economic circulation of the Russian Federation. The losses of year production on these lands are about 7 million tons of grain. Scales and forms of land use cutting depend on geography and extent of grounds degradation. For example, pasturable environmental management already gained oasitic character in the epicenter of desertification of the European part of arid belt – Kalmykia and Dagestan where pastures occupy 80% of farmland.

Desertification of subarid ecosystems in transitional zones is more notable than in the field of real deserts. It is explained by the fact that ecosystems of real deserts are evolutionarily more adapted to the extra-arid conditions. Regional zones of subarid ecosystems collapse quicker, are extremely sensitive to environment violations, their ecosystems are worse restored (Vinogradov, 1993).

Caspian Depression is the only area in Europe where steppe is replaced by semi-desert which forms northern frame of Asian deserts to the East. In the XX century degradation and desertification of lands increased here as a result of inadequate anthropogenous loads of ecosystems.

The main directions of desertification manifestation in the considered territory are weak water erosion and deflation (the last – in a zone of light soils distribution), moderate and strong salinization. The main gain of desertificated lands was noted till 1990 when bogharic agriculture and pasturable animal husbandry were developed. During the modern period many territories were abandonned or transferred to laylands. There is intensive cutting down of natural forest trees on rivers valleys and steppe fires are regular.

In general, according to All-Russian Scientific Research Institute of Agroforestry estimates, from 10 to 80% of the lands relating to the desertificated category are used now in the Caspian region for agricultural purposes. The losses of year efficiency reach 10.3 centners in a grain equivalent per each villager. Such repeated degrading territories are object of the prime complex forest improvement facility and transformation into agroforest, agroforest pasturable, silvopastoral and other forest-agrarian ecosystems.

About 800 thousand hectares of arable lands underwent degradation only in the territory of Volgograd region: the area of washed-away arable land increased by 160 thousand hectares, periodically mentioned deflation and wind-eroded – by 283, salted – by 385 thousand hectares. Annual humus lost is 2-3 times bigger than its collection as a result of water and wind erosion. Only 40 thousand hectares of irrigated lands area among 308 thousand hectares avoided degradation and are used. The efficiency

of capital investments in agricultural production decreases owing to the lands degradation, the risk of all branches increases, agroecological intensity of the territory increases; it has an impact on the demography of rural population.

Along with regularly irrigated lands, the largest and potentially productive massifs of irrigational developed meadow estuaries which in the 70-80th years of last century provided gross collecting up to 500 thousand tons of hay with low prime cost are concentrated in the territory of Volgograd region. Only a half of 58.6 thousand hectares of estuaries is effectively used now and productivity of hay there does not exceed 2 t/ha instead of possible 3.5-4.0 t/ha.

All-Russian scientific research institute of irrigated agriculture determined possible areas of irrigation – 75% thus are provided with large irrigating systems and 25% - with local drain. The developed structure of cultivated irrigated areas in 2005 did not meet the requirements of maintaining effective agricultural production. Corn occupied 3% of space, long-term herbs – less than 10% among the total area of crops.

Local Dzhanybeksky water-supply irrigating system consists of several hundred kilometers of channels ending with artificial ponds and refalse sites abandoned in some years after the beginning of exploitation. It happened, as a rule, less than in 10 years after the beginning of irrigation when gross harvesting was lower than on bogharic lands. The reason of irrigated soils degradation is a raising of salted ground water level up to the depth less than 3 m and secondary salinization of soil and ground water (mineralization to 40 g/l) (Tolpeshta et al., 1997). The reason of ground water level raising is water filtration in earth walls of the channel with formation of salted water domes that excludes efficiency of their transpiration to the plants (Sapanov, 2003).

Steady management of land resources is the most important condition of society development assuming use of soil, water, animal and flora for production of goods meeting the changing needs and requirements of people. At the same time, it has to provide long-term maintenance of productional potential of these resources and preservation of their ecological functions.

The organization of steady land use in arid conditions of semi-desert and dry steppe where deficiency of water and the strongest insolation are natural obstacle of production intensification is the most difficult and regulates human and production resources on a unit of area. Besides, the development of agriculture ways in borders of arid territories, for example, of Russia and Kazakhstan in historical time underwent considerable changes (Sapanov at al., 2015).

We will briefly stop at the present stage which began from 1990th years after the Soviet Union's disintegration. The development of territories returned to market relationship again. This mechanism of productive forces regulation destroyed socialist method of managing, having caused disintegration of integrated farms which ceased to get state support. As a result of agrarian reform consequences in the Republic of Kazakhstan, the removal of unproductive and solonetzic lands from the use there was a reduction of agricultural lands in comparison with 1991 by 9225 thousand hectares or by 3.5 times, including arable land decreased by 1267 thousand hectares or by 2.7 times.

The changes in land use structure on the basis of comparison of satellite images of 1992 and 2004 were shown in figure 1 where abandoning of arable land and formation of deposit, strong pasture and reduction of unpaved network roads is accurately visible (fig. 1).

Now 3648 thousand hectares, including 740 thousand hectares of arable land are assigned to agricultural formations or only 26.1% of farmland area is used. There are over 900 thousand hectares in a deposit from which over 590 thousand hectares (Akhmedenov, 2010) of tillable lands in northern part of the area are the most fertile and moisture provided.

At this stage, sharp reduction of crops and livestock production is noted here, there is a universal overgrowing of weed vegetation of arable lands, disintegration and full death of protective forest plantings (Sapanov et al., 2010), increase in erosive processes, annual uncontrolled fires and other undesirable phenomena.

For example, 901.4 thousand hectares of bogharic arable land brought out of agricultural use in West Kazakhstan region of Kazakhstan from 1988 to 2008. 131,6 thousand hectares in subzone of moderate dry steppe with dark-brown soils were brought out of use for the 20-year period, in dry steppe subzone with brown soils – 349.9 thousand hectares, and in desert steppes subzone and desert zone on light brown soils – 419.9 thousand hectares (Akhmedenov, 2010). The areas of lands captured by water-supply irrigating melioration decreased as well, for example, only 50% from 250 thousand hectares (Onayev, 2014) are used in flood irrigation. The most part of irrigated sites ceased to function.

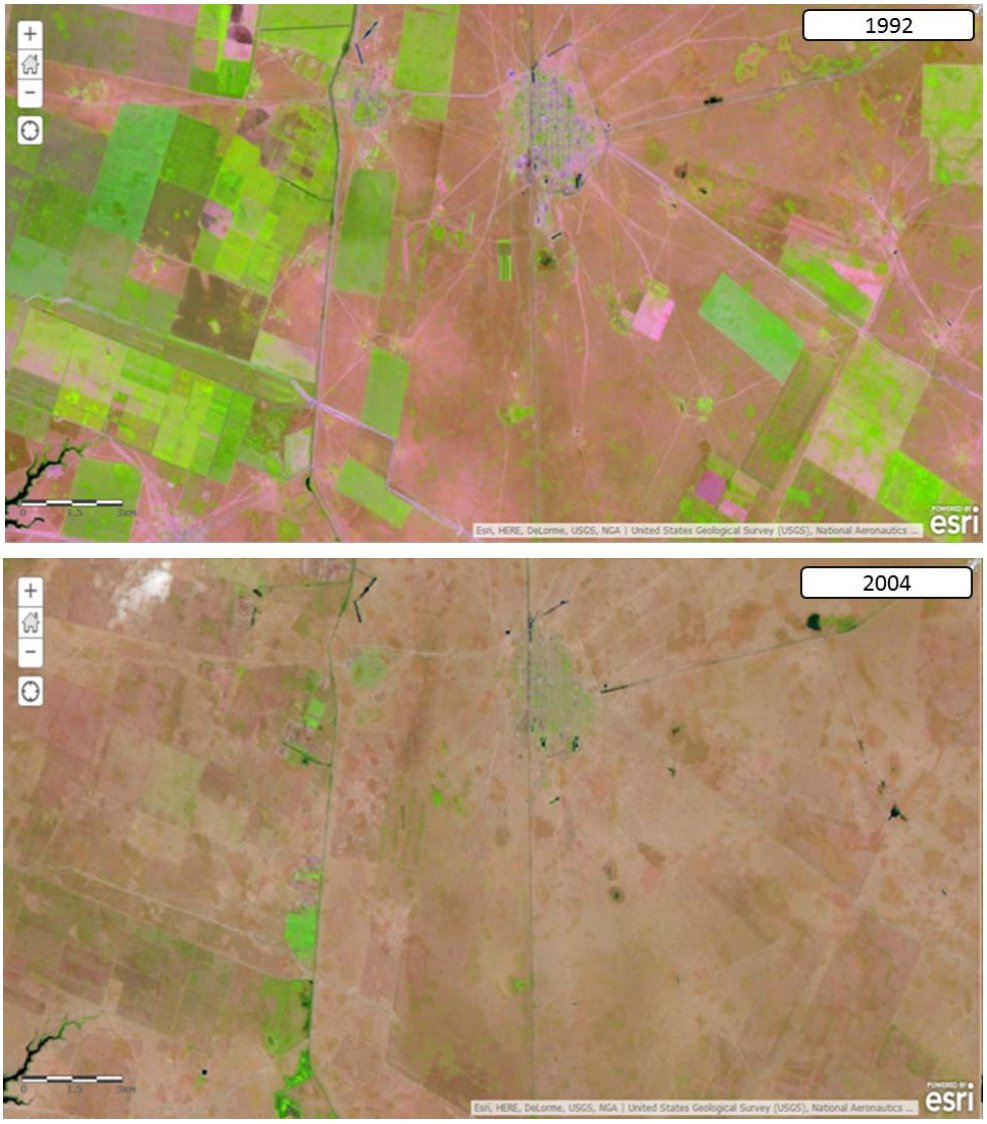


Figure 1. Changes in the structure of land use of the studied territory on the basis of satellite images comparison from 1992 and 2004.

Survived country farms master remained "shepherd's points" with centralized electric network near rare open reservoirs and/or wells. Attempts of these farms to conduct production on "socialist" algorithm by the production of grain crops on big areas with unproductive soils end with failure and ruin again and again. Market economy showed unprofitability of expensive cultivation technologies of a number of crops applied in farms, many of which were considered as progressive not so long ago. It led to the break of crops structure, crop rotations and system of agriculture in general. Attention to crop rotations fell sharply, elementary violations of crop rotation requirements for the sake of market

conditions were allowed. It is shown in single crop expansion. Productivity will sharply fall at such managing, contamination will increase and soil erosion will amplify. So, for example, considerable distortion towards wheat to the detriment of other crops is observed in West Kazakhstan Region in the structure of cultivated areas. Prevalence of this crop in the structure of crops leads to the violation of scientifically based system of crop rotations (fig. 2). Grain and seeds of oil-bearing crops, in comparison with other agriculture products, remained the most demanded in the market, and in comparison with other types of grain - wheat appeared to be the most favorable crop. Now, deepening of grain specialization is accurately expressed in general on the region at considerable reduction of cultivated areas. Insignificant specific weight of sowings of oil-bearing crops testifies that they have not become a little considerable source of income. The reduction of specific weight in cultivated areas of potatoes and vegetables is a sign of self-reliance level decrease of these products of the region in general.

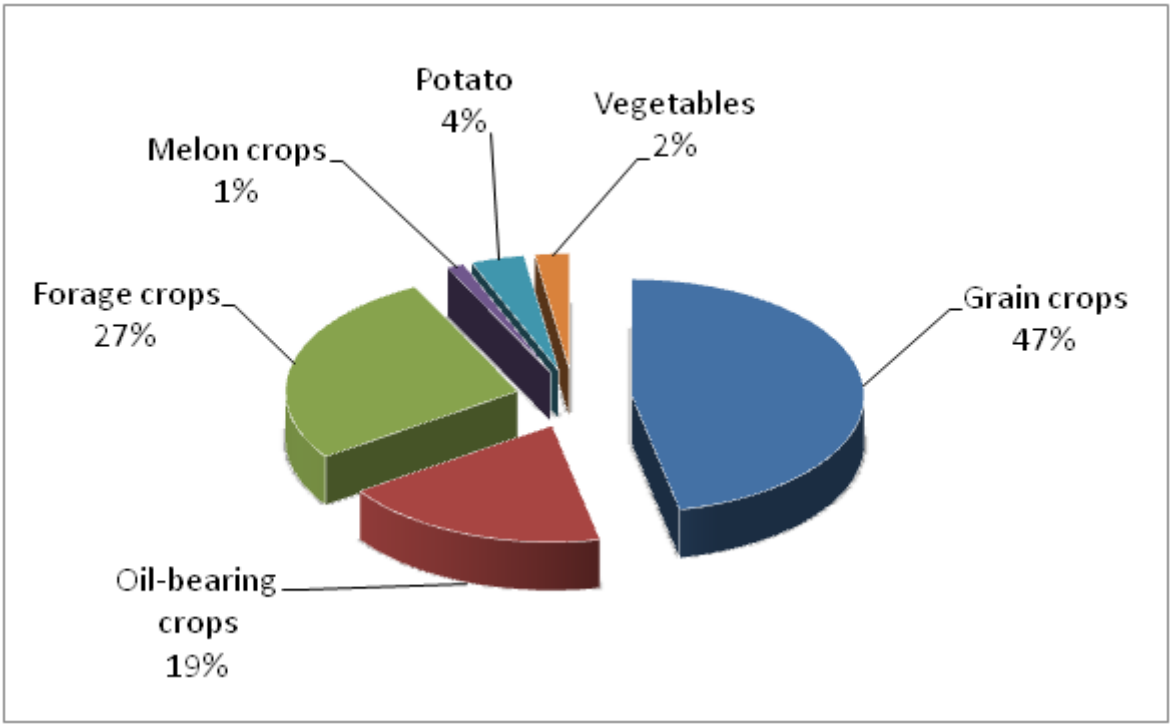


Figure 2. Structure of sowing lands (the whole cultivated area in all categories of farms) of West Kazakhstan Region in 2015

In other words, the reforming of agriculture (rather self-control) happens spontaneously and irregularly, and the program for optimization of environmental management which is accurately formulated by the states in this region (Volkov, 2009; Voronin, 2011) is necessary now more than ever. The number of rural population is reduced promptly and concentrates in large settlements and gets older since the youth migrates to the cities (Braga, 2011).

However even at such scenario of agriculture development, positive moments from the return to natural regulation of population in this territory, and also transition to the reduction of state support of unpromising outdated technologies and productions (through the insurance, subsidizing and other mechanisms) which is not always effective and justified due to the lack of incentive to modernization (Zavodov, Imshenetskaya, 2007; Dmitriyev at al.., 2011) are visible.

The reduction of arable land areas and increase in deposits leads to gradual restoration of arid territories ecosystems. The reduction of domestic animals' loads on pastures, in turn, causes self-restoration and strengthening of ecological framework of steppe agrolandscapes. All this opens new

prospects for the preservation and increase in a biodiversity of these ecosystems. And use of modern methods of managing with application of agroforestal actions gets the importance here.

Primordially treeless southern regions of the former USSR in historical geographical aspect represent huge interest in connection with essential change of environment by implantation of forest plantings which are noticeable even in space pictures.

So large-scale actions were begun after well-known drought and hunger in 1946-1947. At that time it was considered that droughts and dry winds on treeless spaces of Russia arise near the Caspian Sea. In 1948 by the Resolution of Council of ministers of the USSR "About the plan of field-protecting afforestations, introduction of grassland crop rotations, constructions of ponds and reservoirs for providing large steady crops in steppe and forest-steppe regions of the European part of the USSR" the start to well-known "Stalin's (Soviet) Plan of nature transformation" was given for the protection against them, on which it was necessary to plant about 4 million hectares of forest plantings along roads, rivers and ravines, on agricultural fields in treeless territories, and also "State forest strips" and "Industrial oak groves". The works were carried out with the emphasis on great Russian experience of afforestation of the beginning of XIX c.

Unfortunately, this Resolution of Council of ministers was executed partially, but the works on large-scale optimization of environmental management of the main agricultural regions of Russia and Kazakhstan began then. Today there are more than 2 million hectares of planted afforestations which radically changed the landscape image of these primordially treeless territories in a positive side, including, in Kazakhstan Cisural area. This experience needs to be considered at the implementation of social and economic development projects of these regions. For this reason, in our opinion, ecological-geographical man-made heritage carried out for the first time in the world and undeserved forgotten is worth broad studying, discussion and continuation.

Careful attitude to renewable natural resources – water and fertility of soils has to be land use basis in such droughty conditions. These territories are easily exposed to anthropogenous desertification at the violation of balance in natural component ecosystems functioning by technological processes, for example, repasture, cultivation of single-crops, irrigation of salted soils and other productions. In other words, the applied technologies have to be socially significant, ecologically safe, and in market conditions - functionally necessary, low-cost and profitable (Sizemskaya, Sapanov, 2010). These provisions are satisfied at the creation of small profitable country farms located dispersive across the territory and applying resource-saving technologies.

Livestock farms with autonomous housing estate in which the electricity is got due to solar, wind and fresh water energy - from wells have to be a basis of such farms located far from open reservoirs. The quantity of domestic animals on a free pasture has to be proportional to the efficiency of pastures and output of wells. Cultivation of grain crops and long-term herbs in durable agroforestal systems which basis is snow-collecting narrow-band agricultural fields is possible for the providing insurance fodder fund. Each field has to be about 200 m wide where additional water in the form of snow gathers at the expense of single-row forest strips from trees or bushes planted on the field length through each 40-60 m. Such narrow-band fields have to settle down at the distance of not less than 500 m from each other. The creation of durable narrow-band and separated forest stand wood-shrubby grassland systems is also possible in the similar way. Besides, the creation of unwatered gardens, berry bushes and even small massive afforestations for own needs is possible on intrazonal fertile meadow-chesnut soils with fresh lens of ground waters met everywhere in natural decreases of relief (Bolshakov at al., 1983; Efficiency increase …, 1989; Sapanov, 2003; Sizemskaya, 2013). The arrangement of small irrigation sites for drop irrigation is possible here.

The analog the offered model of droughty lands arrangement is agroforestal oasis of Dzhanybek Research Station of Institute of Forest Science of the Russian Academy of Sciences which is located in clay semi-desert of Northern Caspian Region of the Volga and Ural's interstream area. This complex was created most adapted for unwatered (not irrigation) droughty conditions so that man-made ecosystems (agroforestal and grasslands systems, gardens and berry bushes, massive plantings, etc.)

were optimized by moisture security due to the redistribution of water streams: snow masses, spring superficial drain of melt-water and rational use of fresh ground waters.

The concept of adaptive environmental management which demands more extensive discussion and introduction is offered. Thus creation of agroforestal complexes can become a necessary component when forming profitable country farms located discretely in primordially treeless territories and applying resource-saving technologies. The functioning of large power-intensive agricultural complexes, by analogy with state farms is apparently remunerative owing to the need of their continuous dating by the state.

4. CONCLUSION

Modern level of agricultural production development in droughty Caspian region of Russia and Kazakhstan does not meet the requirements of adaptive land use. It is caused by the variety of reasons, in particular, transition to the new market relations and inability to conduct economy with the use of advanced technologies. Livestock farm branch can be the priority in a zone of risky agriculture which this region belongs to. The creation of agroforestal complexes has to become a necessary component when forming profitable country farms located discretely in primordially treeless territories and applying resource-saving technologies.

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