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SOIL PROTECTION OF REPUBLIC MOLDOVA IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

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Abstract. Moldova's economy is dominated by agriculture. Currently, about 45% of Moldova's population is engaged in the agrarian sector and about 21% of GDR is generated by agriculture. Experience of the most successful agricultural sector economies has shown that maintaining a prosperous agricultural sector with the participation of more than 10% of the total population is very difficult. The Republic of Moldova is a small country, extremely vulnerable to climate risks, and the processes of soil degradation are increasingly high. The processes and forms of soil degradation change the hydrological regime, and determine the desertification of the territory. The current state of the soil cover is unsatisfactory and on about 10% of the land is critical. Soil protection in Moldova in sustainable development imposes requirements concerning the implementation of sustainable ecological agriculture that includes measures to prevent and combat all forms of degradation and sustainable land protection.

Introduction

In the Republic of Moldova agriculture is the most vulnerable economic sector to climate change, due to the dependence on weather conditions. Climate variability is a major cause of oscillating crop yields and one of the inherent risks in agriculture. However, the state of decline of the agricultural sector is explained by macroeconomic and structural tendencies: the development of subsistence agriculture in place of commercial; agricultural exports decline; inadequate structure of prices; lower food consumption with increasing share of income spent for food; inefficient system of subsidies to agriculture, focused on short-term goals; lack of funds for investment; excessive fragmentation of terrains as a result of privatization; the destruction of irrigation systems.

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An effective sustainable agriculture, based on technologies, can be developed only through a system of production and long-term preservation of the quality and production capacity of the soils. Chernozems occupy an area of 2510 thousand ha or 70% of the total land area and 78% of agricultural land surface (***Cadastrul Funciar, 2011). The country's food security depends primarily on the quality and level of fertility of these soils. From 1970 until 2010 the score of the agricultural land has decreased from 70 to 63 points. Annual losses as a result of decreasing soil rate is 330 lei for ha of agricultural land and 7.7 milliard lei for the total area studied.

Small farms, with an average size of 1.5 ha, divided into 3-4 lots, occupy 28% of the total area of agricultural land and 34% of the privately owned agricultural land. As a result of intensive use, without the application of crop rotation, fertilizers, soil conservation work, soil quality in these households has worsened considerably; making them vulnerable to climate conditions. The practice of world agriculture confirms that high biological productivity of soils in very small farms is impossible to be obtained and kept for a long term. Land reform in Moldova has not created conditions for increasing soil fertility, sustainable land use, increasing agricultural production, exercising therefore together with droughts negatively impact on the economy (***Sistemul informaţional…, 2000).

1. Agropedoclimatic zones

Moldova is divided into climatic agro-pedological zones which are characterized by parameters that favor or limit the use of land for crops. Affiliation of the greater part of the country at the sub-humid zone with frequent droughts during the growing season of plant requires a complete adaptation of agriculture to drought conditions, taking into consideration the particularities of each zone for sustainable development. Estimates have shown that drought affects up to 50% of winter crops and up to 80% of spring crops (*** Seceta, 2007). The vulnerability and adaptation of the crops will depend on the conditions of climatic zones that will require the use of drought tolerant crops with application of an adequate system of fertilization and tillage (tab.1).

Soils in Moldova are subject to degradation processes, which increase the vulnerability of agriculture to climatic conditions. Areas affected by erosion and landslides, deterioration processes of structure and compaction, dehumification, alkalization, salinization and soil bogging up continue to extend. These processes lead to the disruption of biological cycles, the balance of nutrients and humus, soil profile and decreased damage to their fertility. According to estimates, the damage caused to economy by degradation processes (direct and indirect annual loss) consist of 4801 mln. lei.

Agricultural land use in accordance with the productive potential of soil and climate recourses of each climatic zone will increase the chances of survival of Moldova's agriculture in drought conditions. It is also clear that climate change will have dramatic effects on agriculture and the economy of Moldova. New systems are needed for sustainable management of soil resources to reduce the risks of climate and anthropogenic causes that lead to climate change.

Tab. 1 - Climatic indexes and degree of vulnerability and adaptation of zones

Climatic Indexes	**Agropedoclimatic Zones**			**Average**
	North	**Center**	**South**	
Precipitation sum, mm	513	488	436	473
Temperature, °C	8,4	9,0	9,7	9,0
Water reserve, t/ha	4010	3620	2920	3517
Hydrothermal coefficient	0,9 – 1,1	0,7 – 0,9	0,5 – 0,7	0,5 -1,1
Drought frequency	1 in10 years	1 in 5-6 years	1 in 3 years	-
Reduction of harvest	< 20%	20-50%	> 50%	-
Fall precipitation	70-80% of norm	60-70% of norm	< 50% of norm	-
Increasing, t°C	1-1,5°C	2°C	3-4°C	
Vulnerability degree	**Low**	**Moderate**	**High**	
Adaptation degree	**High**	**Moderate**	**Low**	

The south and south-east of Moldova are most vulnerable to climatic conditions. Increasing temperatures and changes observed in precipitation already affect various aspects of agricultural crops, vineyards and orchards, pastures and meadows. Intensification of erosion degree leads to decreasing of surface of agricultural cultures and crops, the surface of meadows on the slopes and hillsides. The degree of vulnerability and adaptation of the crop will depend on agro-climatic zone conditions that will require the use of drought tolerant crops with an adequate fertilizer application and soil tillage.

2. Soil erosion

Erosion is the main factor of soil cover degradation and pollution of water resources. According to soil surveys, soil eroded area increased over a period of 40 years with 280 thousand ha (in 1965 - 594 thousand ha and in 2010– 878 thousand ha), increasing annually with 7.1 thousand ha. Together with the erosion degree soil fertility decreases: weakly eroded – 20%, moderately eroded – 20-40%, highly eroded – 40-60%, and very strongly eroded – 60-80% (*** Eroziunea solului, 2004).

During the period 1911-1965 ravines surface expanded 2 times (from 14,434 ha to 24,230 ha) and ravines number increased 3 times. After 1965 a part of the

land affected by ravines has been excluded from agricultural use and introduced in the forest fund. This led to a sudden reduction the number and surface of ravines on the agricultural land to 8.8 thousand ha in 1999 and 11.8 thousand ha in 2005 ha. Stopping work of ravines liquidation and irrational management in agriculture conducted to the increase in the recent years of their number and area (Leah T., Cerbari V., 2000).

The annual losses of fertile soil are of 26 million tones, which is equivalent to the destruction of 2000 ha of chernozem with full profile and the loss of humus – 700,000 t, nitrogen – 50,000 t, phosphorus – 34,000 t, potassium – 597,000 t. The cost of land damaged by regulatory cost of land (1 ha = 926 496 lei) is about 1850 million lei.

Indirect losses, expressed in agricultural production consists stable values from year to year. Currently, agricultural production lost due to soil erosion is 525 thousand tons nutrients per arable land and 57 thousand tons of fruit and grape on plantation land. Based on the price of 1.5 lei per nutritive unit and 1 kg of fruits, the cost of harvest lost due to erosion consists 873 million lei.

Annual direct and indirect losses as a result of erosion processes are 2723 million lei. Indirectly, the damage caused by erosion extends to other spheres of human activity (*** Instrucţiune, 2004). Soil erosion in the Republic of Moldova has become a primordial issue that can be solved only at the state level.

Measures to prevent and combat soil erosion:

- Strengthening privatized agricultural land;
- organization and planning of agricultural land (road network, dimension of field size, soil protection forest belts, exhaust system to control surplus of rain water from the slopes, etc.);
- implementation of agro-forest-ameliorative measures on agricultural low productive lands and destroyed by landslides, ravines, very highly eroded soils; creating green belts and forest plantations;
- implementation phytotechnical measures: crop rotation, cultivation of alternative crops in strips, grassing space between rows in plantations, etc;
- using the antierosion agrotechnical processes: soil tillage across the general direction of the slope or contour; implementation of soil conservation works for keeping waste vegetable; cracking; carrying out drainage performance;
- application of selective hydrotechnical measures.

Deep erosion (ravines) is a complicated and expensive process. Therefore more effective is preventing erosion by antierosion measures. The most simple and effective method of their stabilization is forestation and grassing.

3. Soil dehumification

Dehumification of non eroded arable soils is a global process, and stopping it in current system of agriculture is impossible. Humus is one of the main indicators of fertility, that determines the physical, chemical and biological properties of soil. The soil organic matter contains 95% of the total nitrogen, 45% of the phosphorus and 65% of the sulfur. The ensurance of agricultural crops and biota with mineral nutrition depends directly on the amount of organic matter in soil. Experimentally it was established that an increase of the humus content of 1% ensures 1.0 t/ha of grain corn or 0.8 t/ha of winter wheat.

According to the data obtained in 1877, Moldova's soils contain from 5 to 9% humus (average 5.75%). The humus reserve in the 0-20 cm soil layer was about 200 t/ha. During the 100 years of agricultural use the humus content decreased by 35-45%. In 2007 the average content of humus was 3.2%. During the 130 years (1877-2007) the content of humus in the arable layer of chernozems agriculturally used fell by 2.47% or 43% from the initial content of the fallow soil (1877), the annual humus speed reduction being of 0.019% (tab.2).

To form an equilibrated or positive humus balance it is necessary that during the average crop rotation to be incorporated into the soil at least 10 tons of manure. During the agricultural chemical period (1981-1990) were incorporated around 6-7 t/ha of organic fertilizers, 180-210 kg/ha NPK, the rate of perennial grasses consisted of 180-210 thousand ha, crop rotation was respected.

Tab. 2 - Morphological indices and humus content of typical chernozem

Indexes		**1877**	**1960**		**2003**	**2007**
		-	**p.42**	**p.43**	**-**	**p.22**
Horizon, cm	**A**	0-61	0-43	0-44	0-50	0-48
	B	62-91	44-101	45-92	51-98	49-95
	C	92	102	93	99	96
	Effervescence		92	65	70	70
Humus, %	**A 0-61**	**5,718%**	-	-	-	-
	Ahp1 0-22		3,75	3,60	3,32	**3,25±0,14**
	Ahp2 22-36		3,65	3,30	3,15	2,97±0,13
	Ah 36-49		-	-	-	2,60±0,13
	Bhk1 49-70		2,34	2,73	1,94	2,13±0,29
	Bhk2 70-96		1,59	1,57	1,68	1,35±0,28

Humus balance in this period was almost equilibrated. During 1995-2010, the amount of organic fertilizers decreased 60 times and consists 0.1 t/ha, the surface of grasses decreased 4-5 times (***Anuarul Statistic, 2010).

As a consequence, soil humus balance is negative (minus 0.7 t/ha) and erosion losses account – minus 1.1 t/ha. Annually the total humus losses consist of 2.4 millions tones on the agricultural land. Forecast calculations show that if the present scenario is maintained, in 2025 Moldova's soil humus content will decrease under the critical level of 2.5-2.8% and cereal crops formed at the expense of natural fertility will reduce to 2.1 t/ha (tab.3).

Tab. 3 - Prognosis of humus content and cereals crops modification

Year	Humus,%	Reserves in 0-30 cm, t/ha		$N_{mineral}$, kg/ha	Yield prognoses, t/ha	
		humus	nitrogen		winter wheat	corn
1897	5-6	200	10	135	-	-
1950	4-5	150	8	115	-	-
1965	3,5-4,0	180	6	105	3,2	4,2
1990	3,0-3,5	110	5	85	2,5	3,4
2025	2,5-3,0	90	4	70	2,1	2,8

Measures for the remediation of agricultural soil fertility:

- minimization of losses of humus by erosion as a result of implementing antierosion measures;
- restoring and implementation zonal systems of crop rotation with soil protecting effects, decreasing rate of weeding crops and extending the surface of perennial grasses;
- using, production and application of organically fertilizers and composts for an equilibrated humus balance by developing the livestock.
- the rational application of mineral fertilizers in doses of 120-130 kg/ha of NPK in average for crop rotation.

4. Nutrients deficiency in soils

Moldova's soils are relatively rich in nutrients that provide yields of 2.5 t of winter wheat, 3.1 t of maize grain. To obtain higher yields of winter wheat from 4.0 to 4.5 t; corn – 5.0-6.0 t is necessary to apply fertilizers. Experimentally it was established that soil fertilization provides a yield increase of 30-40%.

Studying the dynamic of applying the fertilizers in agriculture during 1962-2010 showed the following: during 1961-1965 were applied 19 kg/ha of NPK and 1.3 t/ha of manure. During this period, the nutrients balance in the soils was negative, and crops accounted to 1.6 t of winter wheat, 2.8 t of maize grain, 19.0 t/ha of sugar beet.

During the period chemicals were used in agriculture (1965-1970) the amount of mineral fertilizers incorporated into the soil increased 9 times and was 172 kg/ha

of NPK, and the quantity of manure increased from 1.3 to 6.6 t/ha. During 15 years (1976-1990) for the first time in the history of Moldova's agriculture a positive balance of nutrients in the soils existed.

As a result, soil fertility increased - the content of mobile phosphorus 2 times and the content of exchangeable potassium by 2-3 mg/100 g of soil. In the 1970-1990 period, as a result of intensive technologies implementation; protection, amelioration and improvement soil fertility measures, the winter wheat yields have increased significantly – 3.5-3.8 t/ha. Farms with advanced agriculture achieved on an average 4.0-5.5 t/ha winter wheat, 5.5-7.5 t/ha maize grain, 45-50 t/ha sugar beet.

Post action phosphorus fertilizers applied in agriculture in the chemical period show favorable manifestation on the crops up to present. According to the prognoses, post action of phosphorus residues accumulated in the period 1965-1990, will manifest up to 2012-2015. Exhaustion of phosphorus residues will lead to lower contents of mobile phosphorus in the soil up to the natural level (low and very low) and increasing the productivity of crops.

In 1990-2005 the application of mineral fertilizers decreased 15-20 times. Currently crops annually extract from soil 150-180 kg/ha NPK. With mineral fertilizers in the soil is incorporated 15-20 kg/ha NPK, which consists only 10% of their export crops. The balance of nitrogen, phosphorus and potassium in the soil became again negative. In the last six years the amount of fertilizers applied in agriculture has increased 2-3 times (from 5-10 to 15-20 thousand tones). But these doses of fertilizers applied are insufficient to form a equilibrate balance of nutrients in the soils (*** COD, 2007).

Measure to increase the fertility of soils

- agrochemical mapping of agricultural land once in 8-10 years to assess the actual fertility of the soil and rationally apply the fertilizers.
- implementation of "Complex Program of recovery of degraded lands and increase soil fertility, Part II. Increasing soil fertility", which includes: optimizing crop rotation; accumulation of biological nitrogen in soil in an amount of 25-30 thousand tons annually by increasing the rate of leguminous in crops rotation to 20-25%; incorporation into soil of 5-6 t /ha manure, total 9-10 million tons; annual application of mineral fertilizers, inclusively: 190 thousand tons of nitrogen and phosphorus.
- implementation of action plan and measures of "Program of conservation and increase soil fertility for 2011-2020".
- rehabilitation of agrochemical service infrastructure, including State Agrochemical Service to monitor soil fertility and rational use of fertilizers.

5.Alkalization and salinization of soils

Ameliorative fund includes steppe solonetzes, slope swamps, irrigated and meadow soils. In 1966-1990 major works were carried out on soil improvement: irrigation, drainage, gypsum amendment etc. The natural conditions of Moldova put irrigation among primary tasks, especially in the south part, where the coefficient of humidity is 0.5-0.6, and droughts frequency is one at 3 years. Irrigation permits to increase yields by 1.5-2.0 times and even more.

Irrigated soils in the 90's made up 308 thousand ha. On the irrigated land were cultivated vegetables (0.8-1.2 millions tons annually), forages and cereals. As a result of irrational privatization and excessive parceling of land, the surface of irrigated soils decreased by 7 times and in 2009 was about 46 thousand ha. Currently the farm land irrigation is performed mainly by local water sources (rivers, lakes, ponds) which are characterized by a high degree of mineralization, alkaline and chemically unfavorable reaction. As a result, appear manifestations of secondary soil alkalization and salinization.

In the 1960-1980 a high volume of ameliorative works was done to improve meadow soil, such as drainage, irrigation and gypsum amendment. In the agricultural cycle were included about 180 thousand ha from 230 thousand ha of flood plain and meadow soils. Recovery of large scale agricultural meadows, regularization of river leakage, not respecting the technical norms of operating drainage system have resulted in the intensification of salts accumulation in the "soil-groundwater", in progressive soil salinization and swamping, compaction and gleyzation.

Ameliorative status of alluvial soil is good – 17%, satisfactory – 34% and unsatisfactory – 49%, the surface consist of 90 thousand ha. Damage caused by the processes of soil salinization and meadow go up to 50 million lei.

In the north and central part of republic are met soil with excess of moisture on about 50 thousand ha. In the 1970-1990 have been improved over 40 thousand ha. In the last 15-20 years the improvement works of soil with moisture excess and the maintenance of drainage system in the working practice have been conducted only in small areas. As result, the current improvement status or drained soil is unsatisfactory (*** Recomandări, 1996).

In the soil cover structure of arable land about 25 thousand ha are occupied by steppe solonetzes which are characterized by low fertility. In the 1965-1990 were made a few attempts to improve these soils after a special technology developed by the Institute of Pedology, Agrochemistry and Soil Protection "Nicolae Dimo", their essence consisting in applied fertilization and gypsum amendment.

Ameliorative measures:

- performing quality monitoring of ameliorative fund (irrigated, drained, chemically amendment soils) to develop forecasts, highlighting vulnerability and improve them.
- carrying out extension of great irrigation works on an area of 100 thousand ha;
- resumption of drainage works of swamps soils, restore of soil drainage system, primary the meadow soil of Lower Prut, gypsum amendment of steppe solonetzes according to the national programs.

6.Active landslides

Landslides affect 80 thousand ha which are likely, under certain conditions, to pass into the category of active landslides. Dynamic growth areas of active landslides on agricultural land is as follows: 1970-21.2 thousand ha, 1980-48.6 thousand ha, 1900-79.3 thousand ha, 2005-85.0 thousand ha. During 1970-1995, as a result of incorrect human activity, the surface of landslide expanded with 62.6 thousand ha, increasing annually by 2.5 thousand ha.

Measures to stabilization landslides:

- building channels to excess rainwater drain, drainage of land in various ways, capture the water costal sources; terrains affected by sliding or slopping hazard forestation;
- recovery of slides land is very expensive, but more expensive is laxity, abandoning the affected area. The simplest and most effective method of recovery is forestation, which will contribute in time to the stabilization and improvement of the ecological status of environment.

7.Secondary soil compaction

The existing system of soil agricultural use leads to compaction of arable stratum. Recently plowed layer of chernozems are characterized by a rough structure with compacted massive structural elements. Under the 0-25 cm layer is highlighted a subarable layer (25-35 cm) very compact, with prismatic, monolithic structure. The content of valuable agronomic aggregates of chernozems is very low (30-50%).

The causes of secondary compaction and structural damage are soil intensive tillage with heavy agricultural aggregates, small share of perennial grasses in crop rotation on the field. The negative effects of soil compaction and destruction are: decreased permeability and water retention capacity; worsening of air-fluid settlement system; increasing resistance to plowing; inhibiting the development of root system; unsatisfactory plowing quality of soils. Following these effects, the soil production capacity decreases, intensifies soil droughts.

Measures to prevent soil compaction:

- implementation of crop rotation with a rate of 20-25% of leguminous plants, including perennial grasses – 10-15%.
- applying organic fertilizers, vegetable residues, composts, green manure;
- autumn plowing once in 4-5 years at a depth of 35-40 cm, to destroy the underlying compacted layer, application of organic fertilizers in optimal doses (40-50 t/ha) once in 5 years, phosphorus and potassium fertilizers in reserve.
- along with the classic work of soil tillage it is necessary to gradually implement "no-till and mini-till" systems for soil fertility conservation and "antierosion agrotechnical system". Application of these systems requires adequate production of agricultural machines for performing several operations simultaneously, with minimal effect of soil compaction.

Conclusion

Soil protection in Republic of Moldova requires implementation of sustainable farming system which includes:

1. Creating farms with large (1000-2000 ha) and medium (400-500) surface in the climatic zones and testing technologies sustainable agricultural system in these households and their gradual implementation on the total territory;
3. Creating the necessary infrastructure for technical and material support sustainable agriculture system (machinery, seeds, fertilizers, fuels, pesticides);
4. Improve the national research and projecting system for the work of organizing and planning and land reclamation in accordance with the needs and requirements of sustainable agriculture system;
5. Creating the infrastructure for training, education, extension and reclamation in sustainable agriculture;
6. Creating a viability mechanism that would provide price policy, tax, credit, and allow farmers implement sustainable agricultural system technologies;
7. Support state implementation of sustainable farming system for all forms of ownership and management.

Implementation of elaborated measures and actions will stop soil degradation, increase crop plants productivity and improve ecological status in the Republic of Moldova.

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