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Degradation of Sierozem Soils in the Ile Alatau Foothils

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Abstract: In irrigated areas of Ile Alatau foothills a major problem is using sierozem soil areas for farming leads to soil fertility decreases, depleting the soil, reduces the activity of biological organisms, which slows down the accumulation of nutrients and reduces crop productivity. The changes occur in the sierozem soils like decreases of amount of humus, variation of soil texture and content of carbonates depend on exposure at northern slopes on unploughed and arables lands. To estimate parameters such as amount of humus, soil texture changes and content of carbonates in sierozem, soil samples has taken from 4 plots made in the test areas located in the foothills of Ile Alatau near the Targap (Almaty/Kazakhstan). Parameters have measured by laboratory methods to determine the level of parameters changes between slope and plain areas. Maps of slope inclination 1:100.000 scale have been modelled by combining geo-information techniques, fieldwork and laboratory analytics. The results explain that the stability of parameters of sierozem soils is higher on the plain areas compared to the slopes. Also has found that the humus loss and soil texture variation processes in arable lands located in slope and plain areas induced by using lands long period and ploughing techniques.

Key words: Soil degradation · Soil erosion · Slope inclination · Amount of humus · Soil texture

INTRODUCTION

Land degradation has many definitions as showed in discussions of Winslow [1]. Desertification has defined by The United Nations Conference on Environment and Development as a land degradation resulted from various factors (climatic variation and human activities) in arid, semi-arid and dry sub-humid areas. "Degradation is the deterioration of the soil quality, which gives life associated with the violation of its physical, chemical or biological properties and leading to instability of the ecosystem. The land degradation negatively influences on ecological integrity and yields productivity of 2 billion hectares or 23 % of a landscape used by a man [2]. The main causes of soil degradation are unsustainable agricultural practices, excessive use of pastures for animal feeding (overgrazing), deforestation [3, 4].

Arid and semi-arid regions of Central Asia and Kazakhstan are particularly vulnerable to degradation of different types, particularly soil degradation: loss of fertility, salinization, waterlogging; desertification; degradation of pastures due to overgrazing and excessive agricultural and timber harvesting [5]. The degradation manifests itself in water and wind erosion, salinity, waterlogging, compaction of soil, depletion and desertification processes, which, in turn, accelerate the cycle of soil degradation.

Water erosion as the main cause of soil degradation which is observed in some regions of Kazakhstan like in Almaty. The total area of agricultural lands, incurred to water erosion is about 5 million hectares including 1 million hectares of arable lands. The biggest areas of washed off soils are located in the southern (2.1 million hectares) and western (1.27 million hectares) parts of Kazakhstan [2]. The development of water erosion related to deficient watering system, big furrow slope, unsuitable irrigation methods and other related aspects.

The desertification of land is a degradation of lands in droughty, semi-droughty and dry areas in result of various factors. According to the Ministry of Ecology and Protection of Environment, about 179.9 million hectares or 66% of the land area of Kazakhstan is subjected to land

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degradation and desertification [6]. The area of weak degraded soils covers about 4.5 million ha, medium degraded soils cover about 5.2 million ha and severely degraded soils cover about 1.5 million ha and 0.7 million ha of irrigated lands are subject to severe loss of organic matter [7].

In Kazakhstan, desertification process more actively, which was associated with the mass plowing (40 to 80% of the territory) of unploughed land occupied with natural vegetation land in 1950 - 1970. This has led to the development of wind and water erosion, reducing the capacity of the steppe soil humus. Processes dehumification covered about 4.5 mln. ha with slight extent, moderate - 5.2 mln. ha, strong - 1.5 mln. ha of arable land [8]. Humus loss and changes of soil structure quality occurs in the world. These processes are caused by intensive treatment by ploughing land, insufficient insertion of organic fertilizers [9].

The process is exacerbated because of the improper use of the data areas agricultural practices and activities in agriculture; growing grazing pressure on the remaining land in the unploughed land occupied with natural vegetation state is 2-6 times higher than normal. On the irrigated area of 2.3 mln.ha or 50% of the area in need of reclamation. Irrigated farming is essential for food production in Kazakhstan. Prior to transition to the market economy approximately one third of agricultural products came from irrigated lands, although this represented only 5-6 percent of the farmed area. In southern Kazakhstan the produce from irrigated farming often represented 2/3 of the total produced in Kazakhstan. Over 70 percent of water is used for irrigation. At the same time the efficiency of production per irrigated hectare does not reach the optimum level [10, 11]. The efficiency of irrigation farming and its further development in Kazakhstan are determined mostly by the availability and quality of water resources. The ever-growing demand for water is continued deterioration of water quality. As a result of pollution require urgent and efficient measures to safeguard sustainable development of agriculture and fisheries and other important sectors of the national economy [12]. Main irrigated lands are located in the Southern part of Kazakhstan which cover 5 mln. ha or 80 % from irrigated lands, however water resources especially in the southern part are limited [13].

To fully understand the impact of human activities such as using lands for agriculture by comparing with natural unploughed land occupied with natural vegetation lands, it is necessary to consider the except to which anthropogenic and natural effects have modified the level of amount of humus, soil structure in the soil texture and carbonate content in soil.

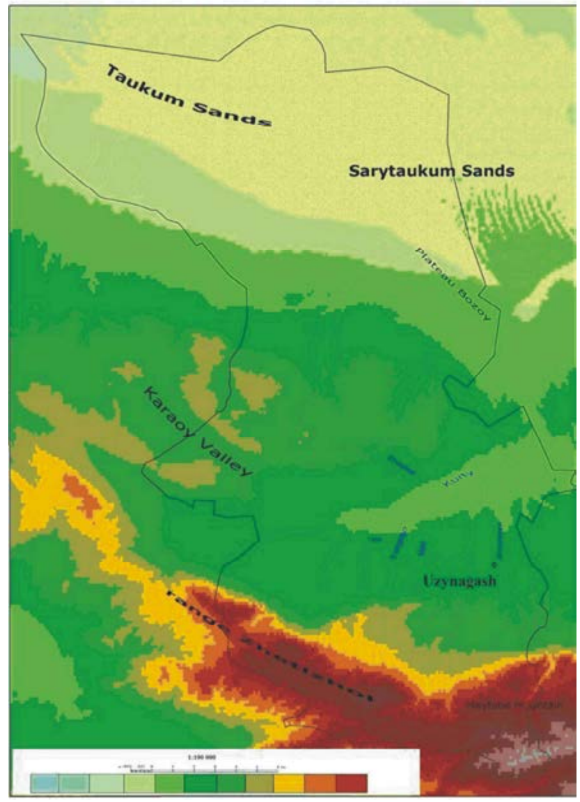

Fig. 1: Zhambyl District (Almaty/Kazakhstan)

Study Area: The study area located in the south-east part of Kazakhstan in the desert zone and belongs to the northern subregion [14, 15]. Total area of Zhambyl district is 19 300 km^2 with administrative center Uzunagash. The territory becomes more flat to the north and bordering with Sarytaukum and Taukum desert massive sand areas (Fig. 1).

Hydrological network heads in the mountains and belongs to the Kurt river basin. Some of these rivers dry up in summer. The role of these rivers is very important for irrigation system of arable lands (Fig. 1).

In irrigated areas of Ile Alatau foothills areas farmers confronted with difficulties of using sierozem soil areas that makes problems losing fertility of soil, which caused by runoff and irrigation problems. The presence of various natural conditions and terrain types imposes different requirements for the location of irrigation farms and the elements of irrigation techniques in irrigated areas.

MATERIALS AND METHODS

Water erosion is a potential danger in the foothill area of sloping plains of Ile Alatau.

Considerable harm of erosion affects on natural grazing lands of Almaty region, especially in pastures, located on the slopes. This is the cause of the destruction of the soil, lunge valuable components of pasture grasses, particularly cereal. In the area of secure and with lack rainfall lands crops are located on the side slopes of 2° to 12° or more.

The main soil type, which is typical for the region, is sierozem or xerosols soils [16]. The sierozem soils are found in arid regions which characterized by a brownish-gray surface on a lighter layer based on a carbonate or hard-pan layer [17, 18].

Ordinary sierozems develop on loess-like loams and have fully developed profile with a rather noticeable division into genetic horizons.

The rest of the territory (mountainous and foothill-flat terrain) is attributed to the system of vertically distributed soil zones in the Tian Shan and Pamir-Alai mountains within the Turan geological province [19].

To show how irrigation system affects to the soil degradation of slope and plain areas on unploughed and arable lands was made a field, laboratory and GIS methods used data like amount of humus, soil structure and carbonates in soil. To measure all these factors have been created the slope inclination map of Zhambyl District (1:100 000) to show the slope inclination of territory. According to the composed maps test area located on foothills of Ile Alatau and main area is located at a height 700-800 m which on 3-5 and 8° slopes. Sierozems of Zhambyl District located on heights between 320-1750m. on sierozem subzone of the desert zone and situated on Balkhash-Alakol valley.

To determine comparative measures of degradation processes on sierozem soils was selected observation area on the south – west part of Targap village situated 100 km from the Almaty-Bishkek highway.

To explain degradation process in the region we have analyzed and determine amount of humus, soil texture and carbonate content from 20 soil samples in the laboratory condition. We were used following methods: humus content was determined by the Tyurin method modified by Nikitin, carbonate content and soil texture by Kachinski.

To choose plot areas has taken into account the following:

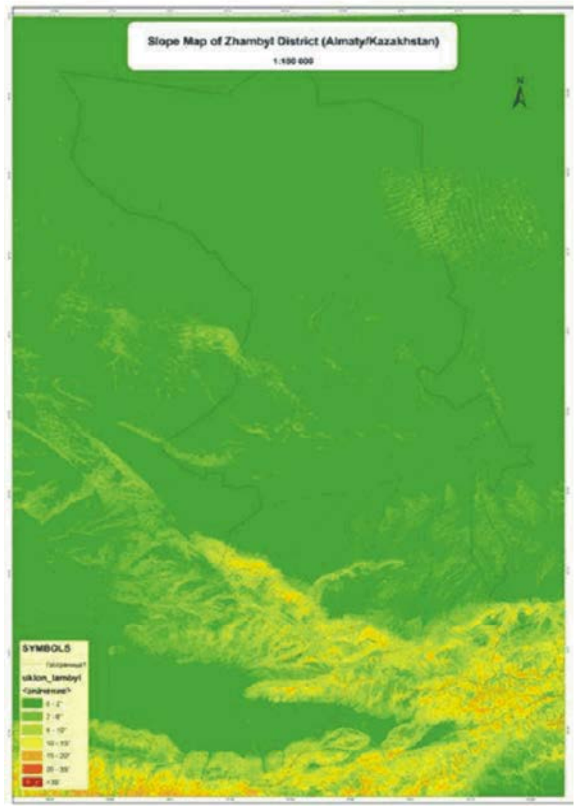

Fig. 2: Slope map Zhambyl District (Almaty/Kazakhstan), 1:100 000.

- Sierozem (natural) soils area located on the 8° slope on unploughed land occupied with natural vegetation and long-term used arable lands for agriculture needs to compare;
- Sierozem (natural) soils located on the unploughed land occupied with natural vegetation and long-term used arable lands on plain areas.

In the chosen place was made 4 sample plots located on the 8° slope and plain areas used for agriculture and unploughed land occupied with natural vegetation. On the soil plots soils profiles were dug. Soil samples for determination of amount of humus, soil texture and carbonates have taken every 10 cm under parent rock. From each plot was taken 5 soil samples with following depth: 0-10 cm; 10-20 cm; 20-30 cm; 30-40 cm; 40-50 cm. Totally was taken 20 soil samples from 4 plots.

In addition, the map (1:100 000) of slope inclination was composed for whole territory of Zhambyl district by using GIS (Arc GIS 10.1 software) and the additional functions of 3D visualization and analysis of building surfaces (Fig.2).

The thematic maps are based first on the digitization of topographic data using analogous maps, which are used later to build a spatial model topography (slope maps, slope exposure). The work was applied by the construction of a TIN model (Triangulated Irregular Network) followed by the calculation of the slope inclination by using the "Derive Slope Function" using the contextual surface mode. Additionally contour lines, roads, land uses, lakes, rivers, elevation points and other information were added into the digital database for further analysis.

RESULTS AND DISCUSSIONS

The main type of soil in the study region is northern sierozem soils. Zhambyl district has the following soils: dark sierozem foothill soils, natural sierozems, north and light sierozem soils.

The territory of Zhambyl district consists of river plains, terrain areas (Fig 1). The movement of water on slopes is governed by a complex set of interrelated factors. The major controlling properties, topographic characteristics such as slope form and angle and positional attributes such as relative height and distance from the slope to base. The slope inclination reaches from 2° up to 45° degrees in mountains (Fig. 2) Increasing of degrees also can influence to landscape degradation and can be also taken into account as a factor of degradation.

The Characteristics of Soil Plots: By the GIS program has calculated the area of sierozem soils located in the Zhambyl District. The sierozem soils are covered 762.200 hectares.

The 1 plot was made in slope of "Zhetyzhol" on the Kozybasy mountain Natural vegetation of this area consist ephemeral plants with *Artemisia and Stipa-Festuca* associations. It's covering 50-60 % of soil surface; mostly of these plants the height reaches 5-10 cm, some of them up to 40 cm. Dominant plants are *Artemisia and Poa*.

Typical geomorphological forms of the region are hilly terrains. Using these fields for agriculture is the main factor that is causing landscape degradation in this area. In that case to know more about this process we decide to make 2 plots also in plain areas.

Humus Amount in the Soil: Humus amount in the sierozem soils decreasing from upper layers by moving down to the lower horizons (Table 1). In unploughed land occupied with natural vegetation lands amount of humus higher if compare with arable lands. This process is explained by the fact that upper layer with enough organic formed from accumulation of organic materials deposited on the surface. In plain areas this index is higher because of unploughed land occupied with natural vegetation lands in slope areas affected by rainfalls (precipitation), surface run off processes loses their light sediments and organics which are moving down and accumulating in the edge of slope with plain area.

Table 1: HumusAmount in the sierozem soils.

	Amount of humus, %			
Soil horizont	1	2	3	4
0-10	0.87	0.74	2.07	0.97
10-20	0.81	0.68	0.97	0.81
20-30	0.76	0.65	0.68	0.62
30-40	0.65	0.55	0.45	0.52
40-50	0.29	0.45	0.42	0.46

The amount of humus in soils in 8° slopes are higher more than 1.17 times in unploughed land occupied with natural vegetation and in plain areas situation is same and more 2 times. This process shows that using lands for agriculture long period and plowing lands 2 times (spring, autumn) are main factors which are going to lose soil fertility and humus in soil horizon. Also roots of plants in soils humus (organic materials) becomes and changes mineral compounds in soils structure. Soils in both slope areas more affects by degradation and this process is higher in arable lands.

Due to the cultivation of land, long period by using ploughing system and irrigating sierozems led to the fact that structure changed, humus deposition have occurred and became more compact.

Soil Texture: Soil loss sand movements in slopes depends on soil structure of region such as soil texture, structure, depth, nature and proportion of clay minerals, vegetation and land use. Soil texture of sloping soils formed on loess parent material, determines their susceptibility to washout.

Soil erosion is affected by soil texture and soil tilth [20]. Light textured soils are less subject to soil erosion by water while heavy textured soils are more erodible, especially ones with low organic matter content. It should be taken into account that the currently used agricultural system on farms with straight roads and fields perpendicular to slopes does not meet soil-conserving requirements.

Fig. 3: Soil plots: 1 - unploughed land occupied with natural vegetation in 8° slope; 2 - arable land in 8° slope; 3 - unploughed land occupied with natural vegetation in plain; 4 - arable land in plain.

Table 2: Information about plots

					By FAO classification (USDA, 1975)		
					Slope class	By regime	
8° slope	Unploughed land occupied with natural vegetation	1	75°49'321 49°19'496	755	Rolling and hilly: dominant slope ranging between 8 and 30 per cent	XEROSOLS	0-16 cm – gray, mid compacted. Mechanical structure of soil cloddy-sandy-dusty. Mid loamy soil with vegetation roots. 6-16 cm - gray, dry, thick, lumpy-cloddy, rootlets, medium loam. 16-32 cm - grayish-brown, dry, compacted, loosely lumpy, medium loam with rootlets. 32-52 cm - brown, wet, compact, loosely lumpy, dusty, with a partly amount of roots medium loamy soil. 52-70 cm - whitish brown, dry, compacted, carbonate, lumpy, medium loam. Closer to this test area we have chosen other plot which are used for agriculture long period and with harvest.
	Arable	2	75°49'427 43°19'543	753			Soil profile of arable land in in 8° slope has the following morphological structure: 0-10 cm – plow land. gray, mid wet, compacted. Can be find a roots of harvest. Breakable-cloddy, dusty light loamy soil. 10-25 cm - plow land also. Brownish, dry, compacted, cloddy dusty. 25-40 cm – lower level of plowed land. Grayish-brown, dry, compacted, lumpy, with less amount of roots loamy soil. 40-55 cm - brownish, dry, compact, dusty, breakable-cloddy. Less rootlet. 55-90 cm – with carbonates, illuvial, gray. Mid wet, less compacted, cloddy-dusty, no rootlets.
Plain	Unploughed land occupied with natural vegetation	3	75°49'308 43°19'515	756	Level to gently undulating: dominant slope ranging between 0 and 8 per cent		Ordinary gray soil, loamy with 60 cm on loess loam soil with carbonate. 0-6 cm - gray, mid moistened, mid compact, lumpy-light-dusty, rootlets, medium loamy soil. 6-17 cm - brownish-gray, dry, compact, lumpy-cloddy with dust, rootlets, medium loam. 17-32 cm - grayish-brown, fresh, compact, loosely-cloddy lumpy, slightly rootlets medium loam. 32-55 cm - brownish, dry, mid moistened, cloddy-lumpy, with carbonate inclusions, medium loam. 52-70 cm - whitish brown, dry, compacted, carbonate, lumpy, medium loam.
	Arable	4	75°49'447 43°19'538	753			Soil: ordinary gray soil north, medium loam with 60 cm on loess soil. 0-10 cm - gray, mid compacted, almost crumbly, moist, unstable lumpy, rootlets, medium loam. 10-25 cm - brownish-gray, dry, dense, cloddy-lumpy, dusty, less rootlet, medium loam. 25-40 cm - grayish-brown, fresh, fresh, thick, lumpy-cloddy slightly rootlets, medium loam. 40-60 cm - brownish, dry, compacted, loosely lumpy dusty, rarely fine rootlets, fine loamy. 60 cm to the bottom brown, but otherwise similar to the previous.

Table 3: Soil texture of the region

			Absolute soil fractions indicator, %						
			Size of fractions, mm						
			Sand		Silt		Clay		
Number of plots	Depth of soil profile	Amount of water, %	1,0-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	0,001	Summary of fractions <0,01
1	0-10	1.66	0.671	16.759	50.030	9.762	11.439	11.339	32.540
	10-20	1.74	0.773	19.439	46.407	10.991	10.584	11.806	33.381
	20-30	1.72	0.570	17.623	50.061	9.768	10.175	11.803	31.746
	30-40	1.62	0.488	20.227	45.945	10.978	11.384	10.978	33.340
	40-50	1.68	0.366	16.640	45.566	13.428	11.798	12.205	37.428
2	0-10	1.52	0.873	20.329	45.897	9.749	12.997	10.155	32.901
	10-20	1.44	0.609	20.657	45.861	11.363	10.147	11.363	32.873
	20-30	1.60	0.630	20.102	44.715	12.195	9.756	12.602	34.553
	30-40	1.50	0.629	20.995	44.294	10.528	10.559	12.995	34.082
	40-50	1.56	0.305	15.583	45.510	11.378	13.815	13.409	38.602
3	0-10	1.52	0.528	18.643	45.898	7.311	15.434	12.186	34.931
	10-20	1.60	0.427	19.085	45.529	11.382	10.975	12.602	34.959
	20-30	1.64	0.447	13.745	48.394	10.167	13.827	13.420	37.414
	30-40	1.62	0.264	15.979	46.138	10.377	14.231	13.011	37.619
	40-50	1.62	0.366	19.130	43.911	11.384	12.605	12.604	36.593
4	0-10	1.90	1.244	17.206	46.483	12.640	11.417	11.010	35.067
	10-20	1.56	0.996	20.175	45.916	10.565	10.564	11.784	32.913
	20-30	1.58	0.630	18.086	47.551	8.535	15.038	10.160	33.733
	30-40	1.52	0.731	23.314	42.242	8.936	12.998	11.779	33.713
	40-50	1.62	0.549	22.606	41.472	9.351	14.231	11.791	35.373

Table 4: Carbonate in soil, %.

	1	2	3	4
Soil horizons	CO_2 %			
0-10 cm	6.49	5.64	4.4	3.54
10-20 cm	6.76	5.81	4.43	5.12
20-30 cm	6.82	6.43	6.33	6.2
30-40 cm	6.95	6.89	6.63	7.02
40-50 cm	7.9	8.5	6.86	8.02

The soil texture the factor which can be used to define land degradation of territory. The soil texture of the region is shown in the Table 3.

Referring to the data given in the table soil of territory is fine textured loamy sierozem. In soils consist high amount of dust (0.05-0.01 mm), sand (0.05-0.01 mm) and clay fractions. Using land long term for agriculture and ploughing conduced reduce of dust and clay and fractions in soil and increase amount of sand fraction in it. This process strenuously occur in 8° slopes because of the movements caused by precipitation and snow melting in spring time surface run-off and strength of extension which affect to the movements of light sediments, particles of minerals and organics from upper to lower levels of areas.

The distinctive feature of soil in the foothills of mountain characterized by mineral compounds in soil, especially by carbonate distinctive feature (Table 4). Due to the fact that sierozems most susceptible to water erosion amount of carbonate anions in soil changes and it is a one indication of degradation process.

Carbonates movements in soil increasing from upper layer of soil and toward to lower layers of soil. It's a typical for sierozem soils as showed in researchers work [21]. Movements and accumulation of carbonates in lower layers of soil result of nature of carbonates which form in the parent rock and by small biological cycle moves up by migration.

CONCLUSIONS

Unsustainable land practices, non-rational use of natural resources have to lead to varying degrees of land degradation and desertification in all regions of Kazakhstan.

The amount of humus in soils in 8° slopes are higher more than 1.17 times in unploughed land occupied with natural vegetation and in plain areas situation is same and more 2 times. This process shows that using lands for agriculture long period and plowing lands 2 times (spring, autumn) are main factors which are going to lose soil fertility and humus in soil horizon.

Soil texture of test area is fine textured loamy sierozem. In soils consist high amount of dust (0.05-0.01 mm), sand (0.05-0.01 mm) and clay fractions. Using land long term for agriculture and ploughing conduced reduce of dust and clay and fractions in soil and increase amount of sand fraction in it.

Rugged terrain leads to varying degrees of sierozem soil eroded. Humus loss on sloping lands caused by the development of planar flush because of the movement down the slope, causing flushing of the upper light layer of soil, which gives the structure of the soil profile.

As described previously, the sierozem soils are characterized by a very sharply expressed carbonate horizon. According to the carbonate content of soils reached 5,64-6,49% for rinse-off areas and 3,54-4,4% in the lowland areas, which shows the level of carbonate, increased by 2 - 2.5% of the study area. What is characteristic of sierozem soil, increases to the bottom and peaked at 40-50 cm in the illuvial horizons (up to 1.5 times).

When used in agriculture is necessary to conduct the event, aimed at erosion control (establishment of anti-crop rotations, tillage and other measures depending on location).

REFERENCES

1. Winslow, M., B.I. Shapiro, R. Thomas and S.V.R. Shetty, 2004. Desertification, Drought, Poverty and Agriculture: Research Lessons and Opportunities. Joint publication of the International Center for Agricultural Research in the Dry Areas (ICARDA), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the UNCCD Global Mechanism (GM), Aleppo, Syria; Patancheru, India; Rome, Italy.
2. Almaganbetov, N. and V. Grigoruk, 2008. Degradation of soil in Kazakhstan: Problems and Challenges. Soil Chemical Pollution, Risk Assessment, Remediation and Security. pp: 309-320.
3. Global Environment Facility, Operating Program on Sustainable Land Management 15. Date Views 10.11.2013. http://www. thegef. org/ gef/ sites/ thegef. org/files/documents/document/OP_15_English_Revised.pdf.
4. Global Environment Facility. GEF Annual Report 2011. Date Views 10.11.2013. http://www.thegef. org/gef/ sites/thegef.org/files/publication/GEF_AR-2011-_final.pdf.
5. Pachikin, K.M. and O.G. Erokhina, 2011. Geographical and genetic researches for years of independence of Kazakhstan.Soil science and Agrochemistry, 4: 14-29.
6. Commission on Sustainable Development, UNDP, Country Profile Report, World Summit on Sustainable Development, Johannesburg, 2002.
7. Saparov, A., 2006. Soil fertility and crops Productivity. pp: 244.
8. The program on combating desertification in the Republic of Kazakhstan 2005-2015. Date Views 10.11.2013. www.unccd.int/ Action Programmes/ kazakstan - eng2005.pdf.
9. Fertilizers and their use, 2000. A pocket guide for extension officers. Food and agriculture organization of the united nationsinternational fertilizer industry association. Fourth edition, revised, published by FAO and IFA. Rome, 2000. pp: 29.
10. Petr, T., 2003. Fisheries in irrigation systems of arid Asia. FAO Fisheries Technical Paper. No. 430. Rome, FAO, pp: 150.
11. Petr, T., K.Ismukhanov, B.Kamilov, D.Pulatkhon and P.D. Umarov, 2004. Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries Volume II.Welcomme R. and T. Petr, Eds. FAO Regional Office for Asia and the Pacific. Bangkok, Thailand. RAP Publication 2004/17.
12. Ismukhanov, K.H. and V. Mukhamedzhanov, 2001. The use of irrigation systems for sustainable production of agricultural and fish products in the Republic of Kazakhstan.FAO Fisheries Technical Paper. No. 430. Rome, FAO. 2003. pp: 150.
13. Abdulla, S.S., K.M. Enadiy, M.S. Tatyana, A.S. Galymzhan and A. Jilili, 2013. Irrigation erosion of irrigated soils in the foothills of southern Kazakhstan. Journal of Arid Land, 5(2): 166-171.
14. Petrov, M.P., 1976. Deserts of the World. Willey, Chichester, pp: 447.
15. Lioubimtseva, E., 2002. Arid environments in Shangedanova, M. (Ed.), Physical Geography of Northern Eurasia. Oxford University Press, Oxford, pp: 571.
16. USDA, 1975.Soil Taxonomy, Agriculture Handbook, 436: 754.

17. Sybil P. Parker, 2003. McGraw hill dictionary of scientific and technical terms. University of Minnesota.
18. Fitzpatrick, E.A., 1980. Soils. Their formation, classification and distribution. Longman Inc. pp: 353.
19. Genusov, A.Z., B.V. Gorbunov and N.V. Kimberg, 1960. Soil-climatic regionalization of Uzbekistan in agricultural purposes. Tashkent. pp: 117.
20. Suleimenov, M., A. Saparov, K. Akshalov and Z.H. Kaskarbayev, 2012. Land Degradation Issues in Kazakhstan and Measures to Address Them: Research and Adoption. Pedologist, 2: 373-381.
21. Sokolov, S.I., I.A. Assing and A.B. Kurmangaliyev, 1962. Soils of the Kazakh Soviet Socialist Republic, Issue 4. Alma-Ata Oblast. "Science" Press, pp: 424.