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Research Article

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Waterlogging and Soil Salinity Problems under Conditions of Arid Environment[1]

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Abstract The article discusses the results of the data obtained by the author during his stage in Turkmenistan, as an expert of the Islamic Development Bank on effective water use. The evaluations on the base of the observations and collected data showed, that almost 85-90 % of the total irrigated agricultural land of the country require effectively working drainage system, due to low bedding of the water table, appearing as result of water percolations and losses through the unlined bed and walls of the main water conveying structure of Turkmenistan Kara kum Canal, along with losses from the irrigation canal infrastructure, delivering water for irrigation, and enormous quantities of water applied through dominating surface irrigation method. More than 21.8 and 52.6 % of the total agricultural land fund of Turkmenistan suffer from low bedding, with water table depths of 1.5-2.0 and 2.0-3.0 m soil layers. All these resulted in serious soil salinization problem on the soils in the country, where the share of lands with high and average salinity level reaches, as high value as 13 and 59 % of the total agricultural area respectively. It was also estimated that the problems of waterlogging and salinization are most serious, on the lands of Lebapskii, Mariiski and Dashoguskii velayats, located closer to Amu Darya river, than Ahalskii and Balkanskii velayats.

Keywords dry climate, land drainage, waterlogging, soil salinity

1. Introduction

Turkmenistan is a country located in Central Asia, between the Caspian Sea in West and Amu Darya river in East ($35^0 08'$ and $52^0 48'$ N and $52^0 27'$ and $66^0 41'$ E). Climate of the country is sharply continental or subtropical desert with the exception of the inshore zone of the Caspian sea. The borders and administrative divisions of the country, named velayats are shown on Fig. 1.

The land surface area of the country is 491 200 square kilometres and the major part of the land is covered with pastures. On the other side, the soils are reported as poor on humus and rich in carbonates that is typical for dry regions. The area with prevailing desert conditions occupies up to 80% of the whole territory of the country. Karakum appears known as the largest deserts in the world and occupies the whole central part of the country, stretching up to Kazakistan [1-2].

The territory of the country is characterised as zone of deficient watering. Annual average rainfall is in the ranges 76 – 380 mm, while annual evaporation from the water surface reaches as high levels as the borders of 1000-2300 mm levels. Therefore, it could be said that the sum of yearly evaporation is many times higher than that of the of the yearly rainfall, which makes irrigation application a limitation factor for agriculture. The highest average amounts of the precipitations on the territory of the country is measured as 398 mm in the

[1] *Evaluations are based on data estimated by the author during his stage in Turkmenistan as an expert of the Islamic Development Bank on Water Resources Development and Effective Water Use*

mountains, while the smallest amounts of 95-105 mm are observed in the regions above Kara-Bogaz Bay and Northeaster part of Turkmenistan [3].

Recent evaluations show that the cultivated area of the country is about 7 000 000 ha, constituting about 14 % of the total area. However, due to the fact that prevailing climatic conditions are typical for the arid regions, only little more than 2 million ha are under agriculture, due to irrigation water shortage [3]. Although, the perception of Central Asia, including Turkmenistan, as being a uniform area was (indirectly) promoted during the Soviet Union era, ecologically this region is very heterogeneous [4]. Moreover, O'Hara [5] reported that the agriculture in all of the newly independent republics of Central Asia, is almost entirely dependent on irrigation., which makes the access to water essential and plays an important role in the social and economic well-being of the country. Due to inadequate rates of season precipitations in all crop production in Turkemenistan is irrigated [6].

Nevertheless the severe deficit of the precipitations and water resources, and though the strong shortage in water sources to be delivered for the purposes of agriculture, the most of the irrigated cropland of the country is in the vicinity of the Syr Darya and Amu Darya rivers [7] and is irrigated by surface irrigation [8], characterised with high water losses and low irrigation efficiency. Though as pointed by Altiyev [9], water supply in the country should be aimed at achieving peak level of water productivity in all sectors of water use, including water saving irrigation techniques and technologies in agriculture.

The matter of water logging and salinisation of Turkmenistan's soils is widely accepted as one of the most serious environmental problems along with the sharp water scarcity [3]. Evaluations from the mid-1980s onwards related to water logging problems of the country indicates that there has been a significant increase on the lands where the water table is less than 2 m below the surface, and more and more land is becoming saline [10]. Moreover, declining soils and water quality has significant implication for future agricultural development in the country. Lately, the investment for improving the drainage infrastructure has been among the highest priorities of the government, which is constructing the vast Turkmen Lake (also called the Golden Age Lake) in the Karakum Desert to collect saline irrigation drainage water [11].

Due to the climate characteristics, agricultural production in the country is completely dependent on irrigation. According to FAO [2] statistics, total harvested irrigated cropping area was estimated as 2 013 800 ha. and the major crops of wheat and cotton account for 45.5 % and 32.4 % of the total harvested area. Less shares of 1.5, 0.6, 0.5 and 0.4 % belong to vegetables, sugar beet, rice, and potatoes, respectively.

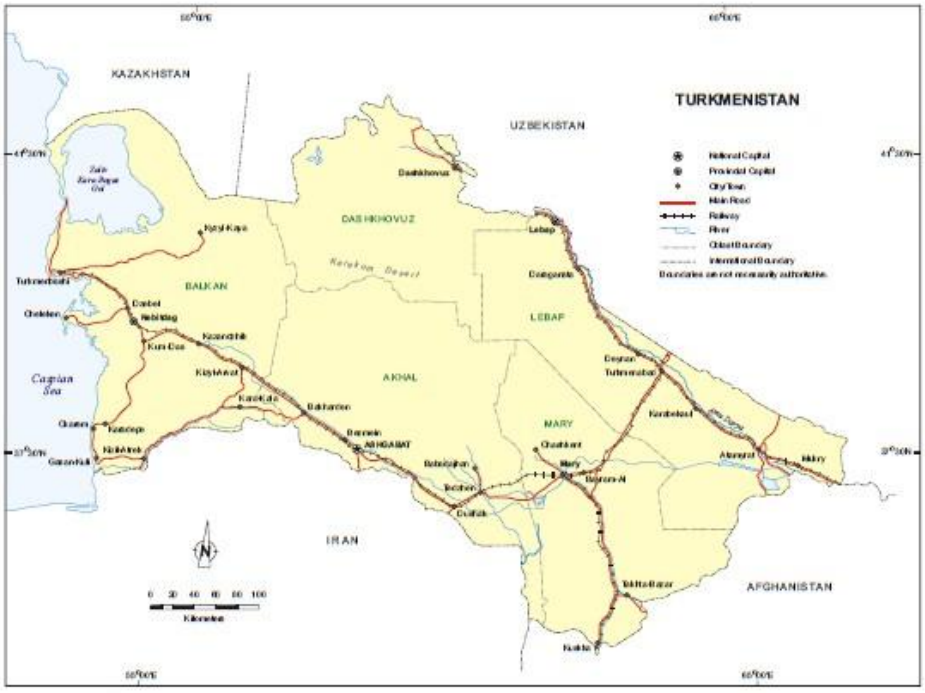

Figure 1: Map of the country with Velayats locations [2]

Irrigation in Turkmenistan is mainly concentrated in oases, irrigated with water diverted from the Murghab, Atrek and Tedzhen rivers, and from the Kara Kum canal, the main hydraulic structure of the country supplying agriculture and population by water diverted from the Amu Darya river, on the border of the country with Uzbekistan in the North.

The prevailing desert climatic conditions with extremely low rainfall quantities on one hand, and very limited fresh water resources on the other, makes the evaluation of drainage waters of relatively low salinity, as a possible water source for agricultural irrigation, that lead to more soil salinity problems along the territory of the country. Moreover, serious problems of water logging is experienced on the major part of the country, especially on the lands of Lebapskii, Mariiski and Dashoguskii velayats. However using drainage waters for purposes of irrigation, have been pointed out earlier, as an eventual ways to solve the water scarcity problems in Turkmenistan [12-14].

2. Materials and Procedures

The main data evaluated in the article are provided from the sources of Water Resources Ministry and Ministry of Agriculture of Turkmenistan as well as from the Research Institute "Turkmensuvylymtaslama" in Ashgabat (Aşkabat). Drainage and tail water discharge data evaluated in the paper are collected from different drainage system structures constructed. Salinity analysis were carried out in the laboratories of the Ministry and the Institute "Turkmensuvylymtaslama" in Ashgabat using methods given by Arinuskina [15]. While evaluations of the laboratory data and classification of investigated waters were performed on the basis of world-wide criteria published in Richards [16]

3. Results and Discussion

The principal water resources of Turkmenistan are Amu-Darya river (22.0 km^3year^{-1}), Murgab (1.6 km^3year^{-1}), Tedjen (0.9 km^3year^{-1}), Atrek (0.4 km^3year^{-1}) and small rivers of Kopetdag (Table 1). Water reserves of the country differ by extremely irregular placement on the territory and 95% of all the water resources of the country are provided by Amu-Darya river and conveyed by the main waterway Karakum canal, 1400 km long and constructed in the 1950s [1-2, 17]. A very limited share of 5% belong to all other rivers, small rivers, springs and underground aquifers withdraw.

Wastewater production was estimated as approximately 1.275 km^3year^{-1} and treated wastewater 0.336 km^3year^{-1} all of which was directly reused [2], however it could be assumed that wastewater do not play a significant role as a water source. While agricultural drainage waters, appeare a substantial additional source for pasture irrigation, growing salt-resistant trees and forage crops and for fisheries. As a result of the investigations the total volume of the drainage water was estimated as 5,6 – 6,0 km^3 per year and some part of the drainage water, as in the case of some collectors in Ahalskii and Dashoguzkii Velayats is with relatively lower salinity level and suitable for the purposes of irrigation [12-14].

Table 1: Mean annual runoff and ground water withdraw in Turkmenistan

Nature of the Source	Source name	Water Amount mln m^3/year
1. Surface Water (Rivers)	1.1. Amu-Darya including Karakum Artificial River	22 000
	1.2 Murgab River	11 000
	1.3 Tedjen River	1 631
	1.4 Atrek River	169
	1.5 Small Rivers	354
		150
	Total surface water	24 304
2. Underground water		1 269
Total 1 + 2		25 573

Water losses through unlined banks of Karakum canal, as well from overall irrigation water delivering and supply scheme and during the process of irrigation has caused massive waterlogging and salinization on the

surrounding land and irrigated area. The process of waterlogging is getting worse due to the surface irrigation method characterizing with enormous water losses and dominating in the country. Water seepage from the irrigation channels also leads to rising of the groundwater levels, or even water logging, and enhanced soil salinization process.

Data summarized in Table 2 point out for the severity of the waterlogging problem across the agricultural lands of Turkmenistan.

Table 2: Distribution of the irrigated lands on the bases of water table level in the country

No:	Region (Velayat) Name:	Irrigated area, ha / %					
		Table water depth, m					
		< 1	**1–1.5**	**1.5 - 2**	**2 - 3**	**3 - 5**	**> 5**
1	Balkanskii	1094	620.0	1201	5402	1570	73743
		1.31	0.70	1.44	6.50	1.87	88.18
2	Ahalskii	392	9205	79634	249968	143868	55537
		0.10	1.70	14.30	46.40	26.70	10.30
3	Mariyskii	989	24381	113267	289154	14979	0.00
		0.22	5.51	25.60	65.32	3.31	0.00
4	Lebapskii	6532	49698	128592	95830	10133	0.00
		2.20	17.10	44.20	33.0	3.50	0.00
5	Dashoguzkii	0.00	9253	62655	289316	24068	26154
		0.00	2.20	15.20	70.30	5.80	6.40
	Total for Turkmenistan	9007	93157	385350	929670	194618	155434
		0.51	5.27	21.81	52.61	11.0	8.80

As could be concluded from data included in the table, the problems of shallow water table and waterlogging are serious for the all agricultural lands of the country. However, the severity of water logging and drainage problem is not similar over all the lands used for agricultural farming. More than 21,8 and 52,6 % of the total agricultural land fund of Turkemenistan have water tables in depths of 1.5-2.0 and 2.0-3.0 m. However, the shares of lands with water tables deeper than 3.0-5.0 m and more than 5 m are estimated as 11.0 and 8.8 % respectively, and could be classified as soils with good aeration and drainage characteristics (Fig 2). The severity of the problem of aeration is much higher on the lands of Lebapskii, Mariiski and Dashoguskii velayats, located close to the Amu Darya river and using irrigation water, diverted directly from the main water source of all the Central Asian countries, including Turkmenistan (Table 2). More than 17, 44 and 33 % of the total land under agriculture in Lebapskii velayat, own shallow water table, located in the depths of 1.0-1.5, 1.5- 2.0 m and 2.0-3.0, respectively. While the share of the agricultural lands with water table levels, deeper than 3.0 m (3.0-5.0 and below 5.0 m is only 3.50 % (Fig 3).

Similar situation exists in Mariiski region, where the total share of the lands with shallow water table in the layers of 1.0-1.5 m and 1.5-2.0 m exceeds 30 %, and more than 65% of the total area possesses drainage waters at 2.0-3.0 m depths. Special care requires lands of the Dashoguskii region, where more than 70 % of the total land have water table fluctuating between 2-3 m soil depth. The lands with appropriate aeration and drainage characteristics in the mentioned two velayats, constitute only 3.5 % (3.0-5.0 m) depth in Mariiskii; and 5.8 % and 6.4 % percents for 3-5 m and below 5 m, respectively of the total lands of Dashoguskii velayat.

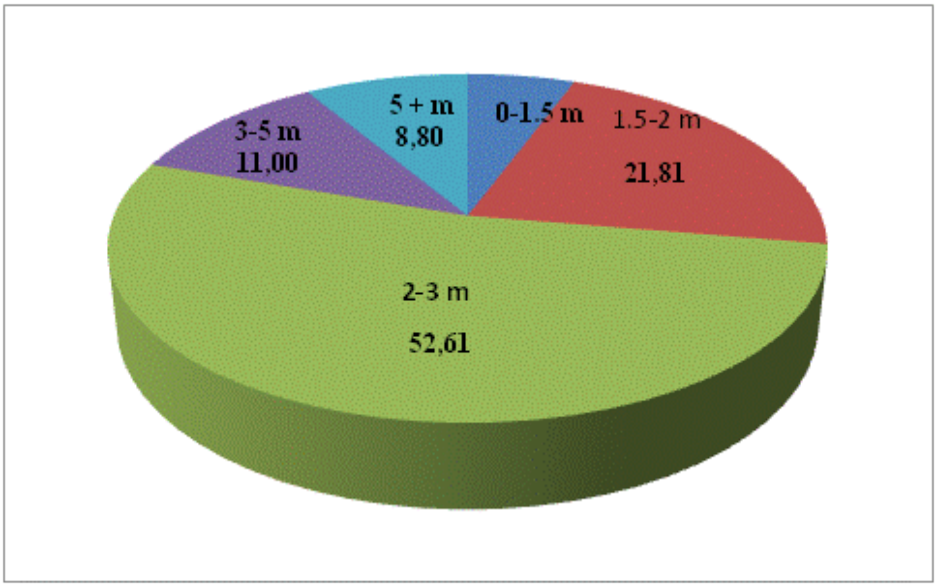

Figure 2: Distribution of the agricultural lands in Turkmenistan according to ground water level

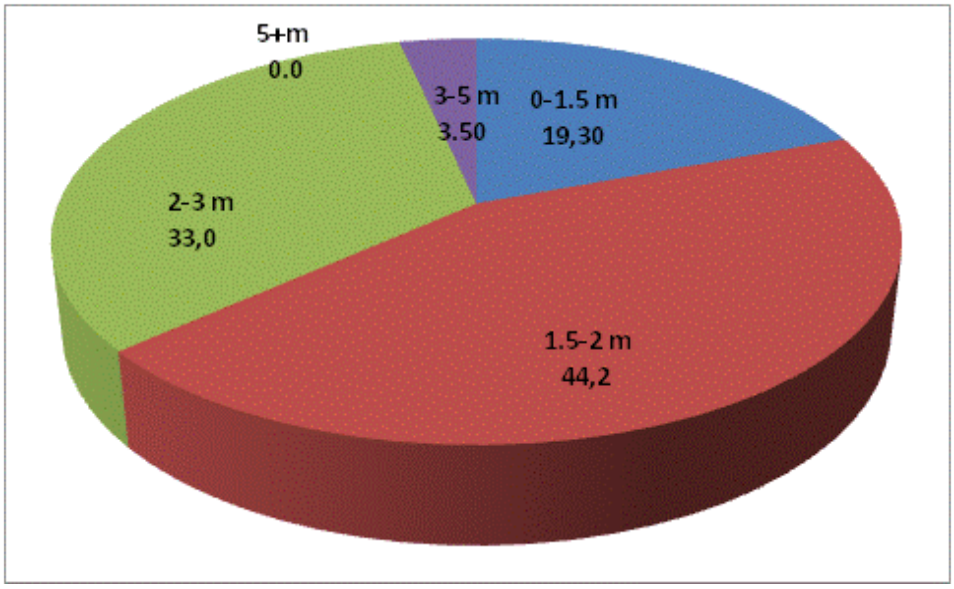

Figure 3: The situation of waterlogging on the lands of Lebapskii velayat

Better is the situation with soil aeration and drainage requirements on the soils of Ahalskii Velayat, where the share of the lands with water table level in the ranges of 2.0-3.0 m, 3.0-5.0 m and below the depth of 5 m, is recorded as 46.4, 26.7 and 10.3 %. On contrary, the portion of lands with poor aeration and severe drainage requirements, due to shallow water table, accounts only about 15 % of the total agricultural area of the region. Almost no drainage problems exist on the lands of the Balkanskii Velayet, since the water table of more than 88 % of the land, is located in layers deeper than 5 m. The piece of the total land with problematic shallow water table level from 0- 2 m, is only about 3.5 % of the total land fund of the region (Fig 4).

Actually, almost 85-90 % of the total irrigated agricultural area in Turkmenistan require drainage system, though effectively working drainage infrastructures have been constructed on about half of the irrigated lands. Approximately 30 % of the total drainage infrastructure is designed as is subsurface working drainage, mainly on lands reclaimed during the last years.

Water losses through unlined banks of Karakum river, as well from overall irrigation water delivering and supply scheme, and during the process of irrigation, has caused massive waterlogging and salinization on the lands. All this resulted in serious soil salinization problem on the soils in the country, where the share of lands with high and average salinity level reaches as high value as 13 and 59 % of the total agricultural area

respectively. Special care is required in order to protect the remainder part of 28 % land, that also own salinization problems in lower extend and are classified as soils of low salinity level (Figure 5).

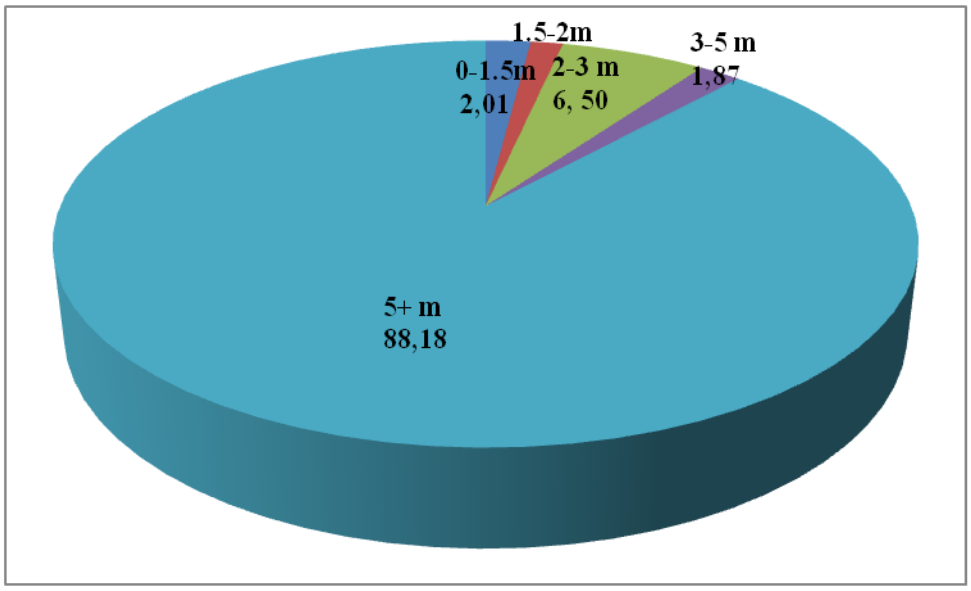

Figure 4: Distribution of the lands according to water table level in the territory of Balkanskii velayat

According to Ovezberdyyeva [18] land degradation appeared mainly due to irregular work of drainage on irrigated lands coupled, with deterioration of irrigation systems and the whole infrastructure of water-management complex, all leading to the rise of ground water levels, as well as to soil salinization and its fertility reduction. Referring to other literature sources the author claimed, that 91.4% of the territory of Turkmenistan is exposed to different forms of land degradation and more than 68% of irrigated lands on the territory of the country, are saline to the medium and severe extent . The author also reported, that about 36% of the irrigated lands are exposed to secondary salinization and waterlogging because of close bedding (up to 2 m) of ground water, and that the mentioned environmental problem is especially pressing for Dashoguz and Lebap velayats.

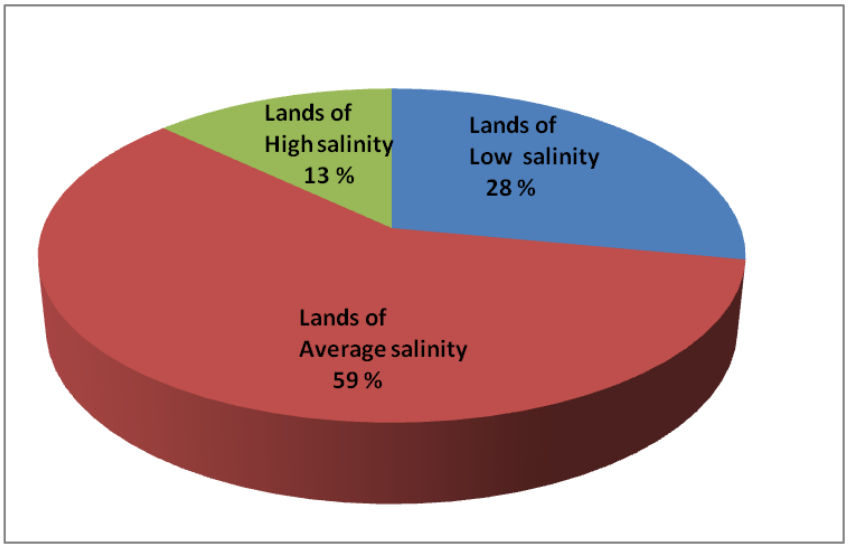

Figure 5: Distribution of the agricultural lands on soil salinity classes

Thevs *et al* [19] concluded that the main reasons for the mentioned situation, is the large gap between the amount of water taken up from the Amu Darya, and the water really used by the irrigated crops. The authors attributed the low water use efficiency in the region to water losses from channels and high amounts of water needed for soil preparation, i.e. leaching of salts. Quite similar view on the these problems were expressed by O'Hara [10], stated the water seepage from the net of irrigation channels resulted in rising groundwater levels

or even water logging, and enhanced soil salinization process. The author concluded also that water logging and soil salinization are major factors, which impact on the agricultural sector in Turkmenistan. In similar way, Akramkhanov *et al* [20], stated that soil salinity was one of the critical factors responsible for the ongoing land degradation in the irrigated lowlands of all of the Central Asian countries, and the negative consequences of irrigation are land degradation through waterlogging, salinization and heavy use of land and available freshwater. Conrad *et al* [21] recently reported, that excess use of natural river water resources for irrigation during the past decades in the Aral Sea Basin (ASB), has caused severe losses in the vital natural ecosystems such as riparian forests and wetlands in delta regions. The authors added also that overuse and mismanagement of surface water in these countries have led to scrutiny of the sustainability of land management.

3. Conclusions

The relatively high average growth rate of the population in Turkmenistan makes the authorities search ways to increase the food production, in order to assure food security and economical growth in the future. However, the country owns very limited water resources which appear a restricting factor for agricultural activities over larger areas under conditions of dry desert climate. Actually the country owns very limited water resources of about 25 mlnm^3/year, which appear a restricting factor for agricultural activities over larger areas, under the prevailing climatic conditions.

Almost 85-90 % of the total irrigated agricultural area in Turkmenistan require drainage system, though effectively working drainage infrastructures have been constructed on about half of the irrigated lands.

Water losses due to deep percolation of water through the bed and unlined banks of the earth Karakum canal, the main water conveying structure crossing the country, along with the water seepage from the net of irrigation channels and enormous water amounts given with each surface irrigation practise, resulted in rising groundwater levels or even water logging, and enhanced soil salinization process. More than 21.8 and 52.6 % of the total agricultural land fund of Turkmenistan suffer from low bedding, with water tables depths in 1.5-2.0 and 2.0-3.0 m soil layers. The severity of the problem of aeration is high on the lands of Lebapskii, Mariiski and Dashoguskii velayats, located closer to Amu Darya river. All this resulted in serious soil salinization problem on the soils in the country, where the share of lands with high and average salinity level reaches as high value as 13 and 59 % of the total agricultural area respectively.

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