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# ASSESSING AND MONITORING LAND DEGRADATION DUE TO SALINIZATION IN TURKMENISTAN AND EXAMINING NEW PHYTOREMEDIATION METHODS

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## 1. Introduction

All the agricultural production in Turkmenistan is grown due to an artificial irrigation. Most irrigation systems exists along the Amu-Darya River and the Karakum Canal (Figure 1). From these sources, a network of channels, which general extent is more than 30 thousand km, distributes irrigation water in the republic. Most of them have opened ground channels. Efficiency of irrigational systems on the average is about 0.60. The significant part of water is lost on filtration, as a result the extensive areas along the irrigation channels become useless for cultivation of agricultural crops. Besides, about 3 $km^3$ of drainage water with different mineralization degree (2-20 g/l) are dumped in a desert, annually, and therefore about 30 thousand ha of rangeland territory is lost every year. In this connection the development of the new and improvement of the existing phytomelioration technologies as well as selection of the salt-resisting sorts of plants for the increase and restoration of the productivity of the degraded lands using the light-mineralized drainage waters is extremely actual for Turkmenistan. The development of the cultivation technology (phytomelioration) of wild galophytes on the saline grounds of Daschoguz velayat represents a special interest.

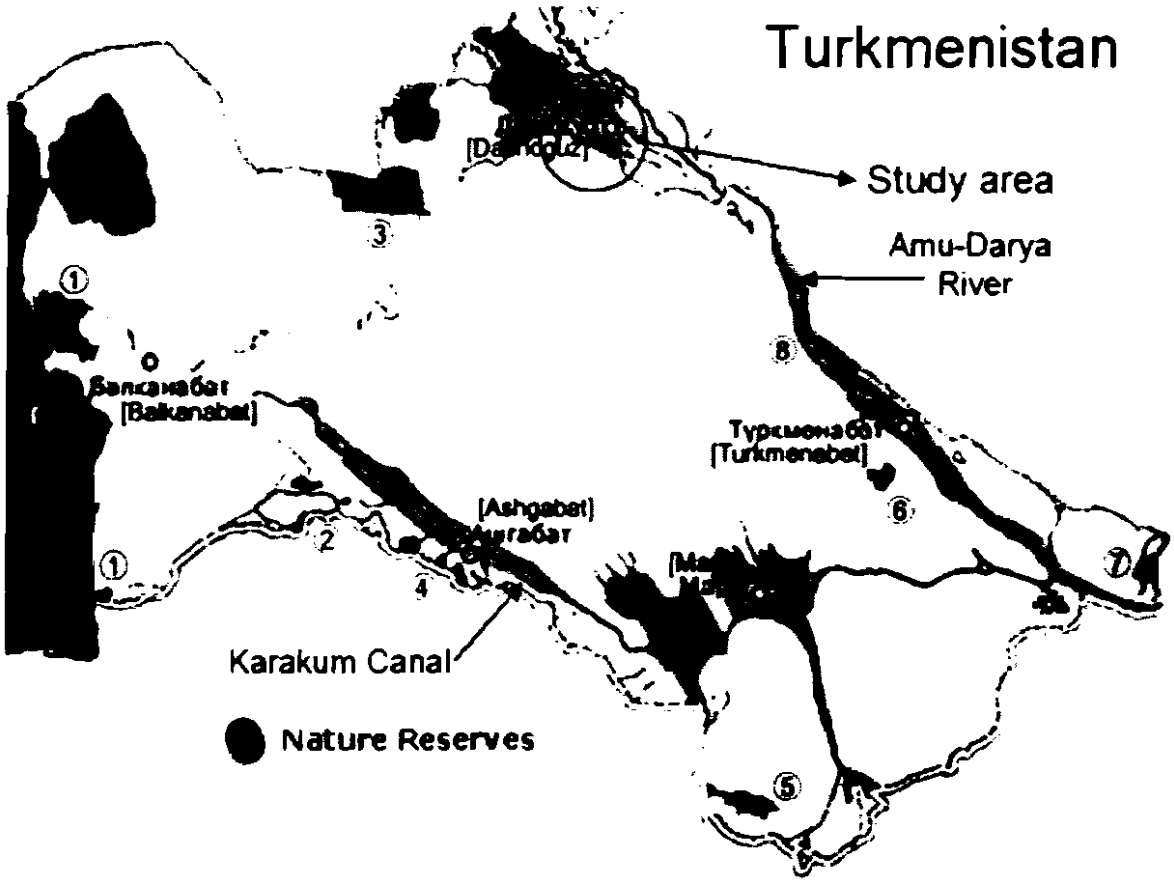


*Figure 1: Study area*



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## 2. Study area

The Daschoguz region is situated in the North of Turkmenistan (Figure 1) and occupies the part of ancient and present delta of the Amu-Darya River. The total area of Daschoguz region is 7.46 million ha.

On the basis of warmth and humidity of vegetation period and local peculiarities of the air circulation in Turkmenistan the 7 agroclimatic regions are selected. The area of research is within the Low Amu-Darya agroclimatic region and occupies a stripe of the irrigated lands around the lower reaches of Amu-Darya. It is the coldest district of a flat part of Turkmenistan. The average annual air temperature is fluctuating within the limits of 11-12$^0$C. Temperature in January, the coldest month –ranges between 4.7-6$^0$C. The average temperature of the warmest month (July) is about 27$^0$C. An absolute maximum of the air temperature is 44-45$^0$C.

A small amount of the precipitation is typical for this region – 76-90 mm per annum. The hydrothermal factor equaled 0.08 is typical for the extremely dry zone. The average monthly relative humidity – maximal in winter - 77-79%, goes down in the summer period to 38-42%. The average annual relative humidity is 56-59%.

January-February period in 2002 was rather cold. The minimal air temperature reached 8.7 $^0$C, although the average decade temperature never fell below zero and was within the limits of 0.0-7.2$^0$C (Appendix A). The temperatures on a ground surface fell to -12$^0$C, but the ground frosts were not observed. 22.9 mm of the atmospheric precipitation took place during this period. March was cool but not cold, although the minimal air temperature in the beginning of the first decade fell down to -6$^0$C. The average decade temperature in April was within the limits of 12.9-14.7$^0$C. In the beginning of the first decade the frosts on the grounds were still observed (-1$^0$C).

An average decade relative humidity was rather high - 55-63%. The monthly average air temperature in May was 19.9$^0$C. The amount of the precipitation in April-May period was 72.4 mm, and considering the precipitation of the winter period, the winter-spring period can be called wet for this region.

The warmest month of the summer period was July. An average month air temperature reached 29.8$^0$C. In the middle of July average decade ground temperature (5-40 cm) warmed up to 33.8-37.2$^0$C. Maximum temperature of the ground surface in this period reached 68$^0$C. The autumn was warm. Frosts have appeared at the end of the first decade of November (on November 8$^{th}$ the minimal air temperature has reached -4$^0$C). Further the air temperature began to fall down. The winter was cold. In December 2002 - February 2003 the average decade air temperature was positive only twice - in the first decades of January and February. In other decades it was within the limits of -0.1 -8$^0$C. The coldest month was December; daily average air temperature on December 11$^{th}$ fell down to -12,5$^0$C. In this month the negative temperatures (-0,1$^0$C) of the ground were observed on depth of 15 cm down the surface. Spring was cool. In the second decade of March (average decade air temperature was +5,1$^0$C) in 5 days of 10 the night temperature fell down below zero and in the third decade – only twice. The monthly average air temperature in April was low – 13,2$^0$C, on April 19$^{th}$ at night it has

even fell down to -1,2$^0$C. In May the monthly average air temperature was 20.1$^0$C. Relative air humidity was high within the limits of 52-58 %.

The 2002/2003 was a relatively wet hydrological year. The amount of precipitation during the October-May period was 112.7 mm, 51 mm of them have fall in May as storm downpours.

### 3. Soil survey

Salinization of the soils is one of the main factors of desertification processes in the Dashoguz oasis (about 65-70% irrigated lands in Dashoguz oasis is salt affected). For estimating the degree of salinity in the Dashoguz irrigated area a salinization map, at a scale of 1: 100,000, was compiled in 1991 on the basis of satellite images at a scale 1: 200,000 (1988-1990 years) and aerial photographs at a scale 1: 30,000 (1988-1990 years).

In the field, different classes of salinity (non- and slightly salinity, moderately salinity, heavy and very heavy salinity irrigated soils) were selected. Each class of salinity includes 15-20 objects. The accounts of optical density were made on Microphotometer МФ-4М in Moscow State Center 'Priroda'. It was found that optical density (D) decreases with the increase of a degree of salinization. So, for slightly salinized heavy loamy soils average D = 1.370, and for very heavy salinized soil D = 0.620

Table 1 presents the optical density values of natural objects in the Dashoguz oasis.

*Table 1. optical density values of natural objects in the Dashoguz oasis.*

| № | Soil type | Number of measurements | D | D average |
|---|---|---|---|---|
| 1 | Slightly salinization on sandy and clay sandy soils | 15 | 0.990 | |
| 2 | Slightly salinization on light (easy) and middle clay sand soils | | | |
| | Slightly salinization on heavy loamy and loamy soils | 15 | 0.700 | 1.020 |
| 3 | Moderately salinization on sandy and clay sandy soils | 15 | 1.370 | |
| 4 | Moderately salinization on light (easy) and middle clay sand soils | 15 | 0.839 | |
| 5 | Moderately salinization on heavy loamy and loamy soils | | | |
| | Heavy salinization on sandy and clay sandy soils | 15 | 0.743 | 0.727 |
| 6 | Heavy salinization on light (easy) and middle clay sand soils | 15 | 0.600 | |
| 7 | Heavy salinization on heavy loamy and loamy soils | | | |
| | Very heavy salinization on sandy and clay sandy soils | 15 | 1.200 | |

| | | | | |
|---|---|---|---|---|
| 8 | Very heavy salinization on light (easy) and middle clay sand soils | 15 | 0.760 | 1.216 |
| 9 | Very heavy salinization on heavy loamy and loamy soils | 15 | 1.690 | |
| 10 | Solonchaks | 15 | 0.791 | |
| 11 | Lakes | 15 | 0.814 | 0.743 |
| 12 | Settlements | 15 | 0.624 | |
| 13 | Within oasis sands | 15 | 0.348 | |
| 14 | | 15 | 5.331 | |
| 15 | | 15 | 1.676 | |
| 16 | | 15 | 0.503 | |

The description of chemical composition of the soils, up to the depth of 100 cm, is given in the Table 2.

*Table 2. Chemical composition of soils*

| Depth sampling, cm | Solid residual, % | $HCO_3$ | CL | $SO_4$ | Ca | Mg | Na | Type of salinity | Degree of salinity 0-100 cm |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | | | | 101. | Solonchak | | | | |
| 0-25 | 1.612 | 0.35 | 4.73 | 18.64 | 15.25 | 3.66 | 4.46 | Chloride-sulphate | |
| 25-50 | 1.032 | 0.33 | 1.85 | 13.26 | 9.34 | 2.55 | 3.55 | Sulphate | |
| 50-75 | 0.982 | 0.35 | 2.37 | 11.46 | 5.70 | 2.23 | 6.25 | Chloride-sulphate | |
| 75-100 | 1.399 | 0.32 | 2.96 | 19.34 | 7.78 | 4.68 | 10.16 | Sulphate | |
| 0-100 | 1.256 | | | | | | | Sulphate | Heavy |
| | | | | 102. | Cotton field | | | | |
| 0-25 | 0.350 | 0.47 | 1.34 | 2.72 | 2.07 | 0.61 | 1.85 | Chloride- | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | sulphate | |
| 25-50 | 0.646 | 0.41 | 0.86 | 7.87 | 5.70 | 1.83 | 1.61 | Sulphate | |
| 50-75 | 0.588 | 0.35 | 1.10 | 6.51 | 4.98 | 1.22 | 1.76 | Sulphate | |
| 75-100 | 0.418 | 0.32 | 0.83 | 4.67 | 3.11 | 1.02 | 1.76 | Sulphate | |
| 0-100 | 0.500 | | | | | | | Sulphate | Moderate |
| | | | | 103. | Tillage | | | | |
| 0-25 | 0.336 | 0.43 | 1.38 | 2.72 | 1.65 | 1.02 | 1.33 | Chloride-sulphate | |
| 25-50 | 0.340 | 0.43 | 1.50 | 2.66 | 1.45 | 1.12 | 2.01 | Chloride-sulphate | |
| 50-75 | 0.272 | 0.43 | 1.26 | 1.93 | 1.24 | 0.71 | 1.67 | Chloride-sulphate | |
| 75-100 | 0.230 | 0.39 | 0.94 | 1.93 | 1.45 | 0.20 | 1.61 | Chloride-sulphate | |
| 0-100 | 0.291 | | | | | | | Chloride-sulphate | Slightly |
| | | | | 104. | Maize field | | | | |
| 0-25 | 0.878 | 0.31 | 3.12 | 9.17 | 6.84 | 2.04 | 3.72 | Chloride-sulphate | |
| 25-50 | 0.282 | 0.37 | 0.59 | 3.08 | 1.87 | 1.02 | 1.15 | Сульф. | |
| 50-75 | 0.178 | 0.39 | 0.51 | 1.40 | 0.82 | 0.10 | 1.38 | Chloride-sulphate | |
| 75-100 | 0.096 | 0.35 | 0.39 | 0.60 | 0.72 | 0.30 | 0.32 | Chloride-sulphate | |
| 0-100 | 0.358 | | | | | | | Chloride-sulphate | Slightly |
| | | | | 105. | Cotton field | | | | |
| 0-25 | 0.639 | 0.41 | 2.52 | 6.77 | 3.53 | 1.73 | 4.44 | Chloride-sulphate | |
| 25-50 | 0.738 | 0.45 | 1.70 | 8.47 | 5.19 | 1.83 | 3.60 | Sulphate | |
| 50-75 | 0.818 | 0.55 | 1.50 | 9.36 | 5.29 | 2.74 | 3.33 | Sulphate | |
| 75-100 | 0.638 | 0.49 | 1.06 | 7.87 | 4.87 | 1.83 | 2.72 | Sulphate | |
| 0-100 | 0.708 | | | | | | | Sulphate | Heavy |
| | | | | 106. | Cotton field | | | | |
| 0-25 | 0.556 | 0.49 | 1.57 | 5.71 | 1.84 | 1.32 | 4.61 | Chloride-sulphate | |
| 25-50 | 0.755 | 0.47 | 0.79 | 9.75 | 5.60 | 1.53 | 3.88 | Sulphate | |
| 50-75 | 0.457 | 0.59 | 0.82 | 4.93 | 0.93 | 0.70 | 4.71 | Sulphate | |
| 75-100 | 0.318 | 0.59 | 0.83 | 3.06 | 0.72 | 0.20 | 3.56 | Chloride-sulphate | |
| 0-100 | 0.520 | | | | | | | Sulphate | Moderate |
| | | | | 107. | Tillage | | | | |
| 0-25 | 0.299 | 0.57 | 0.71 | 1.90 | 0.93 | 0.30 | 1.95 | Chloride-sulphate | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 25-50 | 0.294 | 0.59 | 0.55 | 2.78 | 1.04 | 0.20 | 2.68 | Sulphate | |
| 50-75 | 0.293 | 0.57 | 0.35 | 3.06 | 0.62 | 0.20 | 3.16 | Sulphate | |
| 75-100 | 0.183 | 0.55 | 0.63 | 1.37 | 1.04 | 0.30 | 1.21 | Chloride-sulphate | |
| 0-100 | 0.249 | | | | | | | Chloride-sulphate | Slightly |
| | | | | 108. | Cotton field | | | | |
| 0-25 | 0.399 | 0.47 | 1.66 | 3.80 | 2.17 | 0.91 | 2.85 | Chloride-sulphate | |
| 25-50 | 0.689 | 0.39 | 1.50 | 8.35 | 5.19 | 1.53 | 3.52 | Сульф. | |
| 50-75 | 0.219 | 0.59 | 1.14 | 1.32 | 1.14 | 0.40 | 1.51 | Chloride-sulphate | |
| 75-100 | 1.118 | 0.53 | 3.82 | 11.53 | 6.95 | 3.57 | 5.36 | Chloride-sulphate | |
| 0-100 | 0.606 | | | | | | | Chloride-sulphate | Moderate |
| | | | | 109. | Cotton field | | | | |
| 0-25 | 1.040 | 0.41 | 6.50 | 8.79 | 3.42 | 2.23 | 10.05 | Chloride-sulphate | |
| 25-50 | 0.342 | 0.43 | 1.85 | 2.85 | 1.56 | 0.81 | 2.76 | Chloride-sulphate | |
| 50-75 | 0.269 | 0.55 | 0.59 | 2.74 | 1.76 | 0.81 | 1.21 | Chloride-sulphate | |
| 75-100 | 0.198 | 0.53 | 0.55 | 1.64 | 1.04 | 0.20 | 1.48 | Chloride-sulphate | |
| 0-100 | 0.462 | | | | | | | Chloride-sulphate | Moderate |
| | | | | 110. | Tillage | | | | |
| 0-25 | 0.445 | 0.49 | 1.77 | 5.82 | 2.38 | 1.53 | 4.17 | Chloride-sulphate | |
| 25-50 | 0.846 | 0.39 | 0.83 | 11.70 | 8.09 | 2.74 | 2.09 | Sulphate | |
| 50-75 | 0.556 | 0.43 | 0.51 | 6.09 | 4.87 | 1.32 | 0.84 | Sulphate | |
| 75-100 | 0.535 | 0.43 | 0.35 | 6.04 | 1.14 | 0.40 | 6.88 | Sulphate | |
| 0-100 | 0.595 | | | | | | | Sulphate | Moderate |
| | | | | 111. | Tillage | | | | |
| 0-25 | 0.838 | 0.35 | 4.29 | 6.50 | 3.73 | 2.44 | 4.97 | Chloride-sulphate | |
| 25-50 | 0.638 | 0.47 | 2.40 | 5.82 | 3.01 | 2.14 | 3.54 | Chloride-sulphate | |
| 50-75 | 0.296 | 0.51 | 1.16 | 2.67 | 1.55 | 0.20 | 2.59 | Chloride-sulphate | |
| 75-100 | 0.448 | 0.51 | 2.23 | 5.56 | 1.55 | 0.51 | 4.23 | Chloride-sulphate | |
| 0-100 | 0.555 | | | | | | | Chloride-sulphate | Moderate |
| | | | | 112. | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0-25 | 0.710 | 0.33 | 6.82 | 12.52 | 6.33 | 4.89 | 8.45 | Chloride-sulphate | |
| 25-50 | 0.689 | 0.37 | 0.60 | 9.33 | 5.39 | 2.74 | 2.17 | Sulphate | |
| 50-75 | 0.398 | 0.49 | 0.34 | 3.73 | 2.38 | 0.20 | 1.98 | Sulphate | |
| 75-100 | 0.132 | 0.49 | 0.30 | 0.92 | 0.41 | 0.10 | 1.20 | Chloride-sulphate | |
| 0-100 | 0.482 | | | | | | | Chloride-sulphate | Moderate |
| | | | | 113. | Tillage | | | | |
| 0-25 | 1.544 | 0.37 | 2.57 | 18.34 | 12.66 | 5.29 | 3.33 | Sulphate | |
| 25-50 | 1.504 | 0.37 | 1.76 | 16.31 | 13.49 | 3.66 | 1.29 | Sulphate | |
| 50-75 | 1.374 | 0.43 | 6.49 | 14.59 | 8.51 | 4.38 | 8.62 | Chloride-sulphate | |
| 75-100 | 0.353 | 0.33 | 2.96 | 8.42 | 4.15 | 2.64 | 4.92 | Chloride-sulphate | |
| 0-100 | 1.193 | | | | | | | Chloride-sulphate | Very heavy |
| | | | | 114. | Fallow land | | | | |
| 0-25 | 5.046 | 0.29 | 17.29 | 54.06 | 12.14 | 5.49 | 54.01 | Chloride-sulphate | |
| 25-50 | 1.666 | 0.35 | 3.94 | 19.16 | 14.11 | 2.44 | 6.90 | Chloride-sulphate | |
| 50-75 | 0.813 | 0.33 | 4.51 | 7.91 | 4.15 | 1.12 | 7.52 | Chloride-sulphate | |
| 75-100 | 1.012 | 0.39 | 5.11 | 9.19 | 4.67 | 1.63 | 8.39 | Chloride-sulphate | |
| 0-100 | 2.134 | | | | | | | Chloride-sulphate | Very heavy |
| | | | | 115. | Tillage | | | | |
| 0-25 | 0.190 | 0.55 | 0.98 | 1.32 | 1.04 | 0.61 | 1.20 | Chloride-sulphate | |
| 25-50 | 0.746 | 0.69 | 0.73 | 1.11 | 1.04 | 0.30 | 1.19 | Chloride-sulphate | |
| 50-75 | 0.132 | 0.55 | 0.40 | 1.23 | 0.72 | 0.24 | 1.22 | Chloride-sulphate | |
| 75-100 | 0.126 | 0.59 | 0.34 | 0.71 | 0.62 | 0.10 | 0.92 | Chloride-sulphate | |
| 0-100 | 0.311 | | | | | | | Chloride-sulphate | Very heavy |

The total area covered by the map of salinization of Dashoguz oasis is about 35.000 square kilometers.

## 4. Remote sensing and GIS for assessing salinization rates in Dashogus region

The large-scale dynamics of salinization processes and the present status of degraded lands are studied by geographic information system (GIS) and by remote sensing means. Remote sensing is the most appropriate tool for studying the arid environment and the dynamic processes of its changes in the Dashoguz oasis. The map of salinization entire area of the Dashoguz oasis is divided into 8 parts that later mosaic to create an integrated map. Using the ArcMap program all basic layers were digitized, creating the GIS layers: non- and slightly salinized soils, moderate salinized, heavy salinized, roads, channels, settlements, sands, solonchaks, lakes, farmlands, etc. The total area of the processed parts of the map is 912.35 thousand hectares (9.1 thousand kilometers) or about 25 % of all Dashoguz oasis. The irrigated area of the region is about 584 thousand hectares, including farmlands - 10.2 thousand hectare. The non- and slightly salinized soils - 341.9 thousand hectares (59.5 %), moderate salinized - 134.2 thousand hectares (23.4%), heavy salinized - 80.4 thousand hectares (14.0), the very heavy salinized grounds borrow 18.0 thousand hectares (3.1%). The current report demonstrates the analysis of only one part (Figure 2).

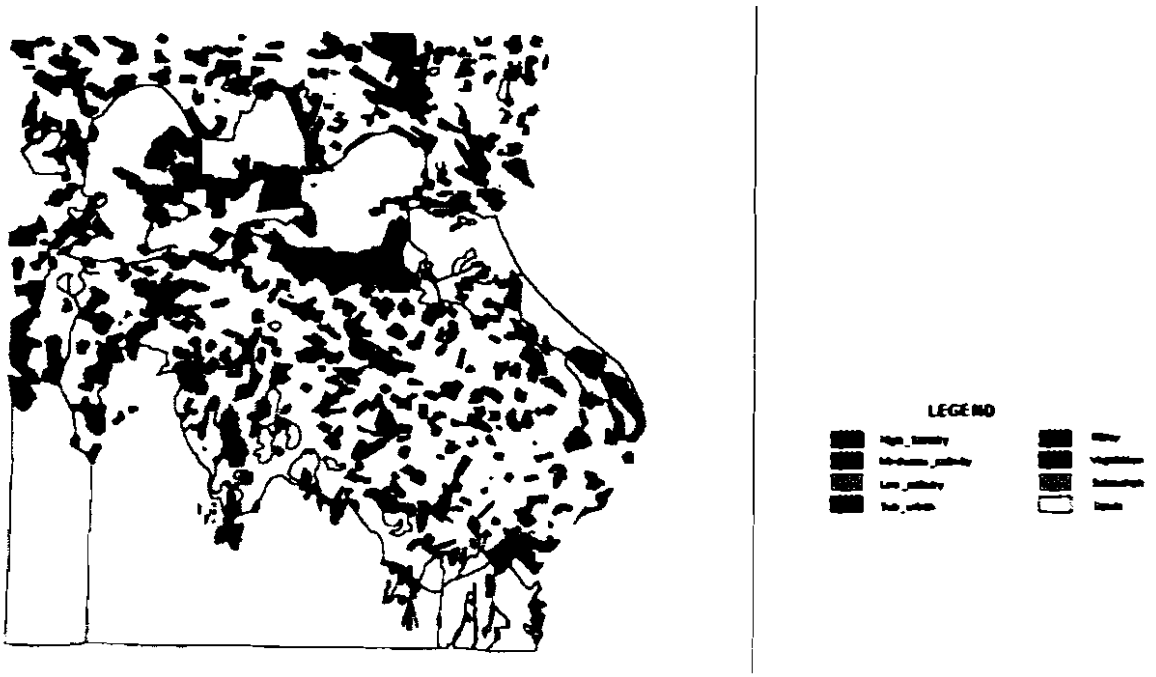


*Figure 2: Digitized land cover/ land used polygons with level of salinities in Dashogus region.*



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A satellite image of the Landsat TM sensor of summer 1988 was acquired covering the entire Dashoguz territory. The image was subject to radiometric correction, atmospheric correction (molecular scattering), and geometric correction. The end product of this process is an image containing reflectance values registered to the maps (Figure 3).

The digitized polygons were overlaid on the Landsat image creating a new map partly showing the digitized landuse/ land cover categories and partly the image ground feature as a background (Figure 4).

For each of the landuse/ land cover categories, the typical spectral signature was extracted. These spectra are presented in Figure 5. It can be seen that for several categories, e.g., vegetation, water, sands, solanchaks, and sub urban the spectra fits well the known spectra from the literature. However, for the other categories that involved salenized soils in different degrees, unique spectra are obtained.

Since the current project is mainly interested in characterizing salenized soils and in assessing the degree of salinity, the next step of processing is masking all categories that are not salenized soils, e.g., water, vegetation, sands, and solanchaks. In this stage, the sub urban area was neglected since it is a relatively small area and since the actual built area (buildings and roads) is rather small. Most of the actual detected area is a mixture of soil and vegetation. For implementing the masking process, the following criteria were followed:
If Band #4 < 0.1 → water
If Band #3 < 0.15 and Band #4 > 0.32 → vegetation
If Band #5 < 0.3 → sands and solanchaks.
The result of this masking process is demonstrated in Figure 6. The rest of the area, after masking, is a bare soil.

In Figure 5 we can see that the low saline soil spectra gradually increases from the shorter wavelength (Band #1) to the longer ones (Band #7). However, when higher salinity exists, the longer wavelengths (Bands # 5 and #6) have lower reflectance values than Band #4. In these cases, Band #5 is a null band. This unique phenomenon has lead to the development of the Salt Affected Soil Index (SASI) that aimed to assess the level of salinity in the study area. SASI is formulated as:

$$SASI = \frac{\rho_7 - \rho_4}{\rho_7 + \rho_4}$$

where ρ is the reflectance in the respective spectral band. SASI values range from −1 to +1, while the negative values indicate low salinity and the positive ones – high salinity.

Results of the SASI values alone are presented in Figure 7 and overlapping the other GIS categories in Figure 8. The level of salinity was divided into 6 sections with respect to the frequency histogram of the salenized pixels.

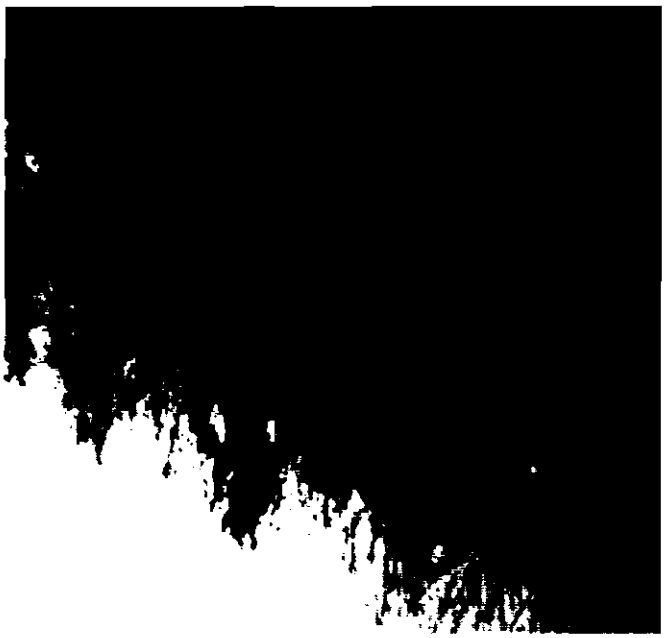

*Figure 3: Landsat image (1988) of Dashogus region (RGB= 4, 3, 2)*

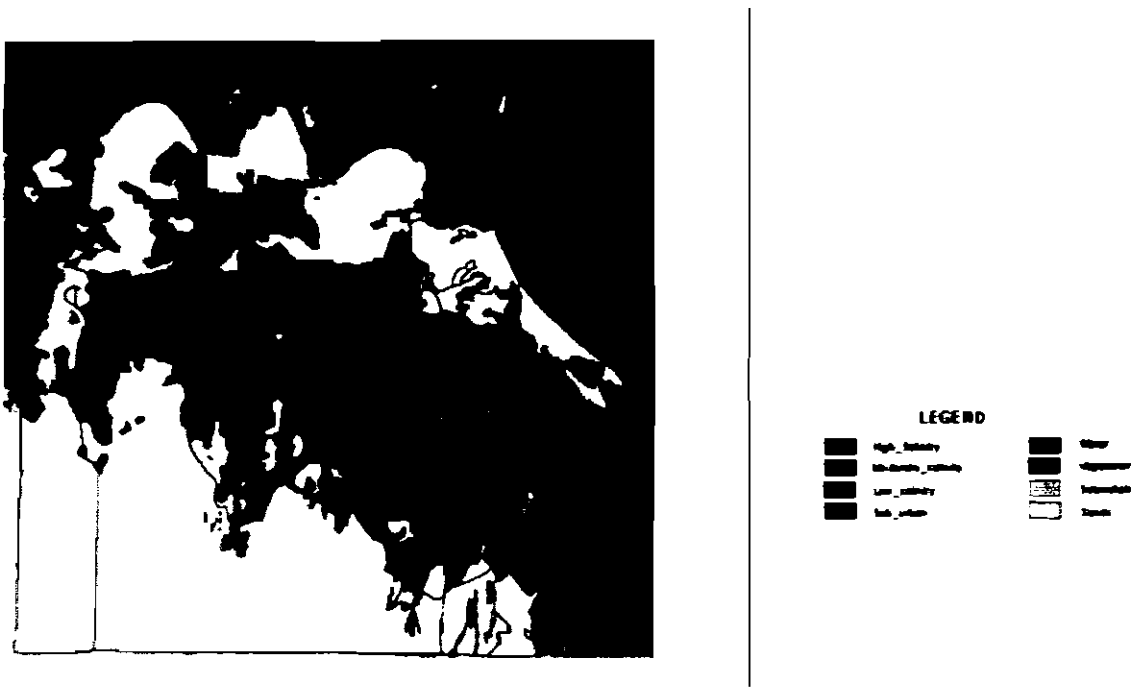


*Figure 4: GIS layes (Figure 2) overlaying the Landsat image (Figure 3).*



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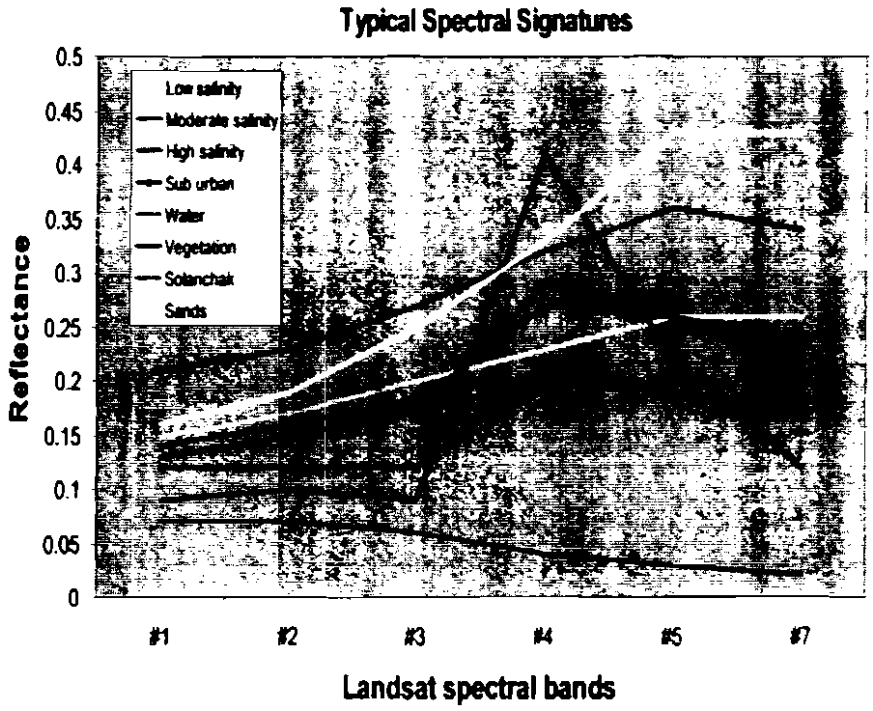


*Figure 5: Typical spectral signatures on the Dashogus region landuse/ land cover categories.*

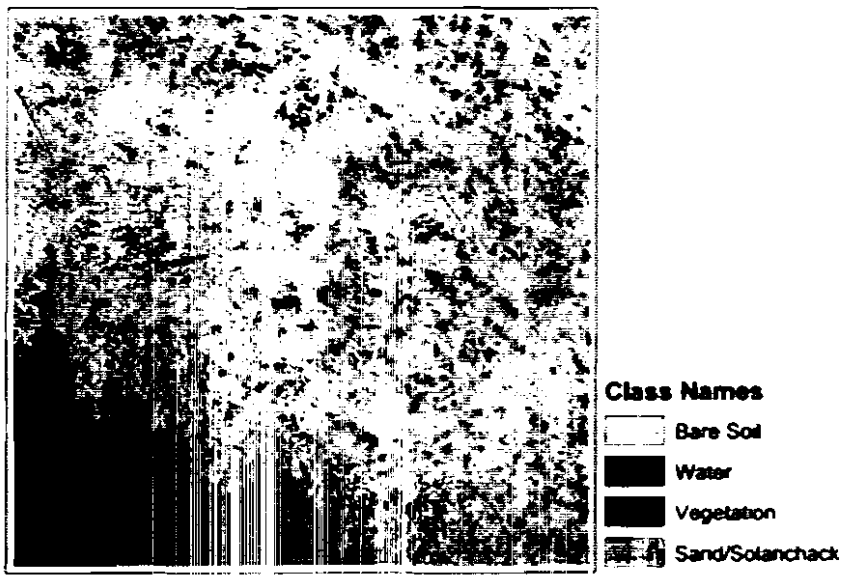


*Figure 6: Image classification for masking water, vegetation, sand, and solanchaks.*



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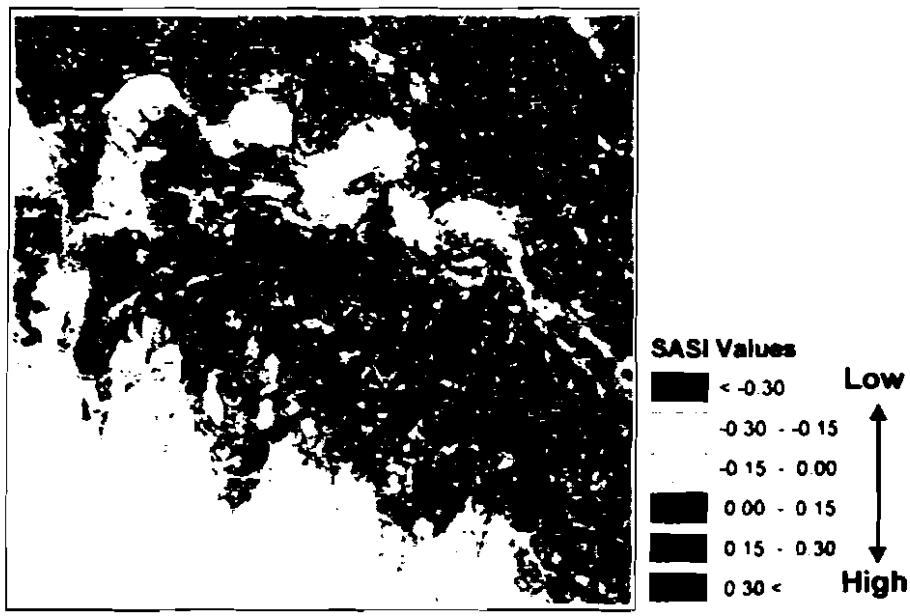


*Figure 7:* Results of the Soil Affected Salt Index (SASI).

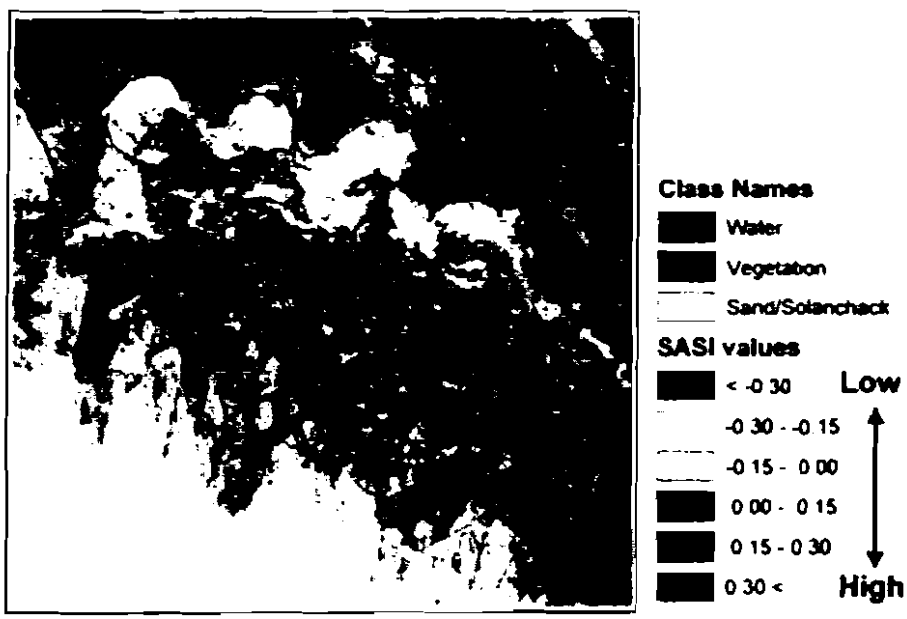


*Figure 8:* Results of the Soil Affected Salt Index (SASI) overlaying the other landuse/ land cover categories.



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## 5. Developing phytoremediation methods

### 5.1 Meliorative conditions of the irrigated areas of Dashoguz oazis

The territory of Daschoguz velayat in it's most part is located at Sarykamysh delta and characterized by low forms of a relief with rather weak inclination to the northwest. In the hydrological relation it is located in a zone of transit and accumulation of subsoil waters, which natural outflow is rather complicated.

The velayat's irrigated area is 326692 ha, 41% of it is saline; 33.5% - mid-saline; 19.3 – hard-saline and 6% are utterly-saline (Table 3).

*Table 3. The characteristic of a salinization degree of the ground*

| Depth of a sample taking | The dry remnant, % | Salinization type | Salinization degree of a layer, 0-100 см |
|---|---|---|---|
| | Plough land after cotton harvesting | | |
| 0-25 | 1.544 | s | |
| 25-50 | 1.504 | s | |
| | | | |
| 50-75 | 1.374 | cs | |
| 75-100 | 0.858 | cs | |
| 0-100 | 1.320 | cs | Utterly |
| | Cotton field | | |
| 0-25 | 0.639 | cs | |
| 25-50 | 0.738 | s | |
| 50-75 | 0.818 | s | |
| 75-100 | 0.638 | cs | |
| 0-100 | 0.708 | cs | Hard |
| | Cotton field | | |
| 0-25 | 1.040 | cs | |
| 25-50 | 0.342 | cs | |
| 50-75 | 0.269 | cs | |
| 75-100 | 0.198 | cs | |
| 0-100 | 0.462 | cs | Middle |
| | Plough land after cotton harvesting | | |
| 0-25 | 0.229 | cs | |
| 25-50 | 0.294 | s | |
| 50-75 | 0.293 | s | |
| 75-100 | 0.183 | cs | |
| 0-100 | 0.249 | cs | Weak |

Note:
s- sulphatic salinization,
c- chloride salinization

Mineralization of the irrigation waters in the main channels changes not only by years (1.24-2.30 g/l), but also by seasons of a year (0.70-1.65 g/l).

The role of irrigation waters in irrigated grounds' salinization at existing norms of water supply (12000 m3/ha and more) is huge. It is annually brought from 8 up to 13t of salts on each irrigated hectare with irrigation waters. Burial of the subsoil waters on irrigated

territory is distributed as follows: < 1.0 m - 2 %, 1-1.5 - 13 %, 1.5-2.0 - 55 %; 2.0-3.0 - 27 % and 3-5m – 3.0 %. The average mineralization of drainage waters in velayat is within the limits of 4.07-5.90 g/l.

Researches are carried out in Geor-Ogly etrap (former Tahtinsky region) that is located in southeast part of Dashoguz velayat. The irrigated area of the region is 43,360 ha. Water supply in the points of выдела is 11.0 thousand $m^3$/ha, removal of salts by drainage is 16.2 t from hectare of the irrigated area. The average mineralization of drainage waters of the area is 5.09 ha/l. The irrigated zone of the territory of a region is different by the close burial of the subsoil waters. Their mineralization changes within the limits of 0.8-6.8 g/l during the vegetative period. Specific extent of a drainage network is 28.5 linear m/ha that is one of the highest among the areas of the region.

Processes of the secondary salinization are caused by high evaporation power from irrigated fields that compound 1480mm and that is 10 times more than the amount of atmospheric precipitation. Dynamics of salinization can be characterized as a stage of seasonal moving salinization and desalinization. 41% of the total irrigation area of 326,692 ha are non-saline and light-saline grounds; 33.5 - mid-saline; 19.3 – hard-saline; and 6.0% - utterly-saline. Our experimental site is situated on the territory of D/U "Turkmenistan", 20 km to the south of Geor-Ogly. The total general area of the irrigated grounds is 2560 ha, 1500 ha of them are saline and light-saline; 560 - mid-saline; 348 - hard-saline and 152 ha - utterly-saline. Experimental site is located on the hard-saline grounds. Measurements of location of subsoil waters in chinks on the experimental site carried out on May 25th have shown that they are located on depth of 1.1m. The chemical compound of subsoil waters on the experimental site is given in Table 4.

*Table 4. The chemical compound of water for 25.05.2003, g/l*

| Selection place | The dry remnant | PH | The dry remnant | $HCO^-_3$ | $CL^-$ | $SO^-_4$ | Salinization type |
|---|---|---|---|---|---|---|---|
| I- chink | 5.92 | 7.88 | 5.92 | 0.36 | 1.67 | 1.81 | SC-MCN |
| II- chink | 8.24 | 7.84 | 8.24 | 0.36 | 2.49 | 2.57 | SC-MN |
| III- chink | 13.01 | 7.46 | 13.01 | 0.38 | 4.19 | 3.70 | SC-MN |
| Drainage collector | 32.02 | 8.48 | 32.02 | 0.27 | 16.76 | 2.06 | C-MN |

Note: SC-MKN - sulphate-chloride in anion part, magnesium-calcium-sodium (MCN).

On February 25th in order to evaluate the dynamics of ground salinization under investigated sorts of plants there had been carried out the drill selection of soil samples 10 cm through up to depth in 1 m. On each platform (5X5) the sampling in fivefold frequency was made. Soil samples from each sort of the plant separately are taken from platforms and then they were separately averaged on the appropriate soil layers. The given method of sampling was carried out in 3-variants (watering with fresh water, collector water and the control without watering). All samples of ground and water were handed to Scientific Research Institute for Rural and Water Management of Turkmenistan. Unfortunately, at present the analysis results are not received. They will be submitted in the following report.

## 5.2 The geobotanical characteristics of the researched plants

Plants in relation to surplus of readily soluble salts in ground are divided in 2 basic groups - glycophytes (plants of the non-saline habitats) and galophytes (plants of the saline habitats). But in nature there is no absolute and distinguishable division of plants in 2 groups, for there are plants with mediate properties, which sometimes refer to a category of facultative galophytes (Shakhov, 1956; Stroganov, 1958). According to the physiological adaptability of the plants to the high contents of salts in the ground, galophytes are divided in 3 groups: salt-collecting, salt-extracting, salt-resisting, and locating salts in special structural formations (Genkel and Shakhov, 1945; Genkel, 1954; Shakhov, 1956).

Salt-collecting galophytes include Salicornia, Suaeda, Haloenemum, Anabasis, Nitraria, Haloxylon aphyllum, which accumulate in their assimilation bodies up to 35 % of dry weight of water-soluble salts (chlorides and sulfates of sodium). Salt- extracting galophytes include Limonium, Trankenia pulverulenta, Tamarix kotschyi. Salt-resisting galophytes include Artemisia, salt-resisting grassy plants. For an object in view of research 4 sorts of salt-resisting plants (Haloxylon aphyllum, Salicornia europaea. Salsola orientalis, Atriplex micrantha) were chosen.

The first 3 sorts are not only steady to the growth on saline grounds, but they are rather valuable in the fodder attitude for animals. Therefore their introduction into culture using light-mineralized waters (3-5 g/l) and use of their physiological properties for desalinization is an actual and necessary problem for the agriculture.

Haloxylon aphyllum - a treelike bush with thick clumsy and a very branchy trunk with dark grey bark. The height of a plant reaches 4.5-5.0 m. It is bred by seeds. It is quite spread in Turkmenistan and grows on the saline soils, the saline sand and takyrlike grounds. In East and Southeast Kara Kum it forms forests that occupy valley-like lowerings in the ridge and hilly sands with more or less lieing and saline subsoil waters. The eaten part of Haloxylon aphyllum in the autumn-winter period are the one-year shoots and fruits. In the summer such forage is eaten bad by animals (sheep and camels) because of the high content of salts.

2001/2002 vegetative year was different by ample precipitation and rather cold and long spring. Within the limits of 30 km away from Ashkhabad the sowing of seeds of Haloxylon was completely absent. It is connected to the fact that the previous year was the driest owing to what the vegetative shoots of the plants were not observed. It is known that generative shoots are basically formed on those one-year shoots of the last year. Gathering of seeds had been spent on November 22-28$^{th}$, 2002 in agrophytopcenosis on Karry-Kul stationery that is 60 km northward of Ashkhabad. The sowing of seeds in agrophytopcenosis was lower than the average perennial. Laboratory researches have shown, that the seeds' quality was very low and did not exceed 40 %. Weight of 1000 piece of seeds was 3.65 (Table 5).

Salsola orientalis - is a little subshrub, 40-50 cm high. It is widely spread Turkmenistan. It grows on gray soils, takyrlike and gray-brown grounds. This plant can be characterized as exclusively drought- and salt-resisting, not requiring to the ground. It is high-valuable forage for sheep and camels on deserted pastures. As usual the mass

ripening of fruits is observed since middle October. In autumn of 2002 Salsola orientalis' seeds have ripened by the end of November. The crop of seeds was rather high. Up to 60-80 g of seeds had been gathered from one middle bush. Weight of 1000 piece of seeds was 5.61g.

Atriplex micrantha – one-year plant, 50-100 cm high. It is met in all areas of Turkmenistan. It grows on saline beams, coastal thickets and frequently met on suburbs of irrigated zones. Gathering of seeds had been spent in middle of October. Two sorts of fruits had been observed. Large – seeds of yellow-brown or olive color, flat, orbicular, 2.5 mm in diameter. Small seeds - black, shining, 1.2-1.4 mm in diameter. Weight of 1000 piece of seeds: large - 1.36g, small - 0.75.

Salicornia europaea - one-year plant, 10-40 cm high. Species are jointed, very juicy with opposite branching and undeveloped foliage. It grows on wet and chubby saline soils. Usually seeds ripen at the end of August - middle of September. In 2002 ripening of seeds had retarded and had been observed in middle October. Gathering of seeds had been spent on November 2-4$^{th}$, 2002. Seeds are covered with uncinate hairs with horseshoe-shaped germ and fiber. Weight of 1000 piece of seeds – 0.48g.

*Figure 5: The weight characteristics of seeds of the researched plants*

| The name of plants | Weight of 1000 piece of seeds |
|---|---|
| Haloxylon aphyllum | 3.65±0.54 |
| Salsola orientalis | 5.61±0.62 |
| Salicornia europaea | 0.48±0.05 |
| Atriplex micrantha A$^x$ | 1.36±0.10 |
| Atriplex micrantha B$^x$ | 0.75±0.08 |

Where: A$^x$ –large seeds
B$^x$ –small seeds

**5.3 Laboratory and field germination of seeds**

The researches on introduction into culture of Haloxylon aphyllum, Salsola orientalis, Atriplex micrantha, Salicornia europaea using light-mineralized waters and use of their ecologic-biological properties for structurization and evaluation of the opportunity of desalinization of hard-saline grounds in Turkmenistan are made for the first time.

In laboratory conditions there had been carried out the researches on the evaluation of an energetic potential of the seeds germination of the sorts investigated. Experiments had been spent in 5-7 multiple frequencies in Petri dishes, on the bottom of which the filtered paper was stacked, and the seeds (100 piece) had been displayed on. The filtered paper had been constantly humidified by distilled water (Tables 6 and 7).

Researches show, that seeds of Haloxylon aphyllum begin to sprout for the second day, and this process comes to an end on seventh day. Quantity of the sprouted seeds from the total number of the seeds being planted was 43 %. The seeds of Salsola orientalis and Salicornia europaea get sprout within one week and only Salsola orientalis' seeds

begin to sprout for the fourth day, and Salicornia europaea for the sixth. Seeds germination of Salsola orientalis and Salicornia europaea is 21% and 91 % accordingly.

Germination dynamics of the seeds of Atriplex micrantha strongly differs from the sorts described above and is characterized by the long period of germination. According to the results received, germination of the large seeds was observed within 48 days and within 19 days for the small seeds. Germination of the large seeds for this period was 24%, small -13%.

In order to count the field germination of seeds and evaluate the preservation opportunity of the energetic potential of germination while seeds were in soil for a number of years, we have sown seeds of each investigated sort in small allotments in 5-7 multiple frequencies (1000 piece on 1 allotment) in field conditions (Table 8).

*Table 6: Energy of seeds germination in distilled water (Haloxylon aphyllum, Salsola orientalis, Salicornia europaea)*

| Day | 28 01 | 29 | 30 | 31 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | Всего |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air temperature, t°C | 20,2 | 20,5 | 20,7 | 21,0 | 21,7 | 22,2 | 24,1 | 24,0 | 23,2 | 25,2 | 22,3 | 20,8 | 20,5 | 22,2 | 21,6 | 20,4 | 21,7 | 21,8 | 22,4 | |
| | Haloxylon aphyllum | | | | | | | | | | | | | | | | | | | |
| Number of sprouted seeds, pieces. | 0 | 2 | 10 | 8 | 6 | 10 | 6 | 1 | 0 | 0 | 0 | 0 | | | | | | | | 43 |
| | Salsola orientalis | | | | | | | | | | | | | | | | | | | |
| Number of sprouted seeds, pieces. | 0 | 0 | 0 | 2 | 5 | 7 | 3 | 2 | 1 | 1 | 0 | 0 | 0 | | | | | | | 21 |
| | Salicornia europaea | | | | | | | | | | | | | | | | | | | |
| Number of sprouted seeds, pieces. | 0 | 0 | 0 | 0 | 0 | 1 | 33 | 17 | 14 | 25 | 0 | 1 | 0 | | | | | | | 91 |

*Table 7: Energy of germination of seeds in distilled water (Atriplex micrantha)*

| Day | 28 01 | 29 | 30 | 31 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | Всего |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air temperature, t°C | 20,2 | 20,5 | 20,7 | 21,0 | 21,7 | 22,2 | 24,1 | 24,0 | 23,2 | 25,2 | 22,3 | 20,8 | 20,5 | 22,2 | 21,6 | 20,4 | 21,7 | 21,8 | 22,4 | |
| | Atriplex micrantha (large seeds) | | | | | | | | | | | | | | | | | | | |
| Number of sprouted seeds, pieces. | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 0 | 4 | 2 | 2 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | |
| | Atriplex micrantha ( small seeds) | | | | | | | | | | | | | | | | | | | |
| Number of sprouted seeds, pieces. | | | | | | | | | | 0,6 | 2 | 0 | 1,1 | 1,1 | 0 | 2,5 | 2,5 | 2,1 | 0 | |
| | | | | | | | | | | | | | | | | | | | | |
| Number of sprouted seeds, pieces. | | | | | | | | | | | | | | | | | | | | |

| Day | 16 | 17 | 18 | 19 | 20 | 24 | 26 | 3.03 | 5 | 8 | 10 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | Всего |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air temperature, t°C | 20.6 | 21.5 | 21.0 | 20.8 | 19.2 | 19.8 | 19.4 | 24.0 | 24.3 | 24.4 | 24.2 | 25.1 | 23.6 | 25.5 | 24.0 | 25.4 | 24.3 | 25.0 | |
| | Atriplex micrantha (large seeds) | | | | | | | | | | | | | | | | | | |
| Number of sprouted seeds, pieces. | 0 | 0 | 1.0 | 0 | 0.5 | 0.5 | 0.8 | 0.8 | 0.4 | 2 | 1.0 | 1.0 | 0 | 0 | 0 | 0 | 0 | 0 | 24.0 |
| | Atriplex micrantha ( small seeds) | | | | | | | | | | | | | | | | | | |
| Number of sprouted seeds, pieces. | | 0.4 | 0 | 0 | 0 | 0.8 | 0 | 0 | | | | | | | | | | | 13.0 |
| | | | | | | | | | | | | | | | | | | | |
| Number of sprouted seeds, pieces. | | | | | | | | | | | | | | | | | | | |

*Table 8: Field germination of seeds of the researched sorts of plants (1000 piece), 25.05.2003.*

| Name of the plant | Germination |
|---|---|
| Haloxylon aphyllum | 10.2±0.2 |
| Salsola orientalis | 1.9±0.1 |
| Atriplex micrantha (large seeds) | 9.0±0.6 |
| Atriplex micrantha (small seeds) | 1.1±0.2 |
| Europaea | 15.0±0.1 |

Researches show, that field germination of the seeds is much lower than that of laboratory. The highest field germination was observed at Salicornia europaea - 15%. At Haloxylon aphyllum it reaches only 10%. Low germination of the seeds of black saxaul is explained by the fact that it was very cold and constantly rainy during mass blooming that strongly prevented the high-grade pollination of the flowers. Germs of the basic part of seeds were poorly advanced in autumn that caused low germination of such seeds. Field germination of the seeds of Salsola orientalis was 1.9%. Field germination of large seeds of Atriplex micrantha was 9%, and small - only 1%. We suppose that the part of seeds of the given sort of a plant is kept in the ground and will sprout the next year.

### 5.4 Introduction into culture of Haloxylon aphyllum, Salsola orientalis, Salicornia europaea, and Atriplex micrantha

The experimental site with sowings of investigated sorts was established in Geor-Ogly etrap of Dashoguz velayat. Sowing of seeds of Haloxylon aphyllum, Salsola orientalis, Atriplex micrantha, Salicornia europaea had been done on January 4-8, 2003. According to the working plan, 3 variants of sowing for each sort researched had been established. In the first variant of experiments, it is supposed to water allotments with sowings of plants with fresh water, in the second - collector-drainage water (salty), in third (control) – the plants are not to be watered.

For improvement of introduction technology of the given sorts into culture, 3 ways of sowing on allotments for each variant had been established: seeds on furrows, seeds'

sowing under a harrow and sowing by lines. Sowing on furrows, when after site plowing and harrowing the furrows on allotment are cut, and then the sowing is made on them. Furrow is a figure in a section of structure of which there lays the isosceles triangle with oval top. Sowing under a harrow, when after processing ground (plowing, harrowing) the seeds of plants being introduced into culture are scattered in regular intervals on a ground surface of the allotments, and then are closed up in ground by secondary harrowing. Sowing by lines includes linear cutting of deepenings in ground (1 cm wide, 0.5-1 cm deep) through 20 cm in length or width of allotments. Then the seeds of plants being introduced into culture are put in deepenings and covered by ground.

Dimentions of one experimental allotment are 5X5m. The area occupied by crops of each sort in first variant is 200 $m^2$. The norm of seeding for all 3 variants is identical. Researches on introduction into culture of Atriplex micrantha, Salicornia europaea had never been spent before. That is why the norm of seeding in 2 experiments was maximal – 40g per allotment, and in 1- minimum - 10 g per allotment (Table 9). The technique used for improvement of technology of sowing of deserted plants is usual.

*Table 9: Number of plants on experimental allotments for 25.05.2003.*

| Techniques of sowing | Norm of seeding on an allotment | Quantity of plants, pieces m² | | |
|---|---|---|---|---|
| | | I-variant watering with fresh water | II-variant watering with collector-drainage water | III-variant without watering (control) |
| Haloxylon aphyllum | | | | |
| Under a harrow | 30 | 10.4±1.0 | 8.6±0.7 | 1.2±0.5 |
| Sowing by lines | 30 | 12.6±3.0 | 17.2±1.0 | 14.4±1.1 |
| Salsola orientalis | | | | |
| Under a harrow | 30 | 5.2±0.4 | 6.5±0.3 | 3.4±0.4 |
| Sowing by lines | 30 | 3.7±0.1 | 5.9±0.1 | 2.8±0.1 |
| Salicornia europaea | | | | |
| By furrows | 40 | 4019±241 | 3346±281 | 3249±129 |
| Under a harrow | 40 | 7108±639 | 5963±476 | 7520±503 |
| Sowing by lines | 10 | 975±50 | 1250±78 | 887±35 |
| Atriplex micrantha | | | | |
| By furrows | 10 | 120±12 | 78±7 | 80±9 |
| Under a harrow | 40 | 172±14 | 151±11 | 205±20 |
| Sowing by lines | 40 | 179±22 | 149±8 | 180±14 |

At the second stage after selection of sowing technology the optimum norm of seeding will be determined. For Haloxylon aphyllum and Salsola orientalis there had been used the average norm of seeding used for sowings for pastures improvement. First shoots of Haloxylon aphyllum and Salsola orientalis have appeared in the third decade of April. Overdue occurrence of shoots is explained by the cold spring. Number of plants in all 3 variants was within the limits of 8-14 pieces per 1 $m^2$. The same parameters of Salsola orientalis change within the limits of 2.8-6.5 plants per 1 $m^2$. First shoots of Salicornia europaea and Atriplex micrantha have appeared in the beginning of the first decade of April.

The account of shoots in sowings by furrows shows that quantity of Salicornia in 3 variants changes within the limits of 3-4 thousand per 1 $m^2$, and in sowings under a harrow - 6-7.5 thousand per 1 $m^2$. When sowing by lines where the norm of seeding is 10g per allotment, number of plants in 3 variants changes within the limits of 0.9-1.2 thousand per 1 $m^2$. At the same norms of seeding number of plants of Atriplex micrantha on allotments was lower and in 2 variants was within the limits of 149-205 plants per 1 $m^2$, and in sowings by furrows where the norm of seeding was 10g per allotment, it was at a level of 79-120 plants per 1 $m^2$. The height of all the plants researched was within the limits of 1-2 cm, therefore their data in the table are not resulted.

**5.5 Conclusions**

1. The samples of ground in investigated variants of sowing are selected for the analysis.
2. Ground water on the site is on the depth of 1.1m, and it's mineralization on the average is 9.1 g/l.
3. In laboratory conditions duration of seeds germination of Haloxylon aphyllum, Salsola orientalis, Salicornia europaea lasts 7 day, the only difference is that seeds of black saxaul begin to sprout for the second day, Salsola orientalis – for the fourth and Salerosa – for the sixth day. Duration of the seeds' germination period of large seeds of Atriplex micrantha is 48 days, small - 19 days.
4. Laboratory germination of seeds of Haloxylon aphyllum is 43%, Salsola orientalis - 21%, Atriplex micrantha: large seeds - 24%, small - 13%, and only Salicornia europaea - 91%.
5. Field germination is much lower than that of laboratory: Haloxylon aphyllum - 10.2%, Salsola orientalis - 1.9%, Atriplex micrantha: large seeds - 9.0%, small - 1.1% and Salicornia europaea - 15%.
6. At a norm of seeding of 30g per allotment (25 $m^2$) the number of plants per 1$m^2$ in 3 variants of sowings of Haloxylon aphyllum and Salsola orientalis was within the limits of 8.6-17.2 piece and 2.8-6.5 piece accordingly. At a norm of 40g per allotment when sowing by furrows the quantity of shoots of Salicornia in 3 variants was within the limits of 3,3-4,0 thousands per $m^2$. When sowing under a harrow - 6,0-7,5 thousands per $m^2$. At norm of seeding of 10g per allotment the quantity of plants changes within the limits of 0.9-1.3 thousands per $m^2$. At a norm of 10g per allotment by furrows, number of plants of Atriplex micrantha in 3 variants was 78-120 piece per $m^2$. In sowings under a harrow by lines, at norm of seeding of 40g per allotment the number of plants in 3 variants was within the limits of 149-205 pieces per $m^2$.

**5.6..Referenses**


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## Appendix A – The climatic characteristics for 2002-3 in Dashoguz station

### 2002

| Month | January | | | | February | | | | March | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Decade | I | II | III | I-III | I | II | III | I-III | I | II | III | I-III |
| Air temperature: | | | | | | | | | | | | |
| Average | 3.9 | 0.0 | 2.3 | 2.1 | 0.0 | 4.1 | 7.2 | 3.8 | 7.4 | 9.1 | 13.0 | 9.8 |
| Maximum | 16.7 | 4.3 | 10 | 16.7 | 9.5 | 16.3 | 20.6 | 20.5 | 22.5 | 22.6 | 31.5 | 31.5 |
| Minimum | -7.0 | -5.9 | -8.7 | -8.7 | -5.0 | -3.8 | -0.5 | -5.0 | -3.4 | -6.0 | -3.0 | -6.0 |
| Air humidity: | | | | | | | | | | | | |
| Average relative | 83 | 84 | 74 | 80 | 83 | 75 | 74 | 77 | 62 | 45 | 43 | 55 |
| Minimum | 54 | 59 | 46 | 46 | 53 | 30 | 38 | 30 | 18 | 26 | -1 | 18 |
| Temperature on a ground surface | | | | | | | | | | | | |
| Maximum | 23 | 11 | 21 | 23 | 18 | 23 | 27 | 27 | 33 | 37 | 58 | 43 |
| Minimum | -8 | -10 | -12 | -12 | -9 | -7 | -4 | -9 | -6 | -12 | 23 | -12 |
| Temperature of the ground | | | | | | | | | | | | |
| 5 cm | 6.0 | 2.6 | 3.7 | 4.1 | 2.1 | 5.2 | 7.4 | 4.9 | 8.7 | 9.6 | 13.2 | 10.5 |
| 10 cm | 6.5 | 3.2 | 3.8 | 4.5 | 2.7 | 5.3 | 7.3 | 5.1 | 8.7 | 9.4 | 12.9 | 10.3 |
| 15 cm | 7.0 | 4.0 | 4.4 | 5.1 | 3.4 | 5.5 | 7.3 | 5.4 | 8.7 | 9.4 | 12.4 | 10.2 |
| 20 cm | 7.1 | 4.4 | 4.6 | 5.4 | 3.8 | 5.5 | 7.1 | 5.5 | 8.6 | 9.2 | 12.1 | 10.0 |
| 40 cm | 9.2 | 7.0 | 6.8 | 7.7 | 6.4 | 7.3 | 8.9 | 7.5 | 10.7 | 11.4 | 13.7 | 11.9 |
| Precipitation. mm | 3.7 | 2.5 | 0.0 | 6.2 | 10.7 | 0.8 | 5.2 | 16.7 | 1.4 | 0.0 | 7.8 | 9.2 |

| Month | April | | | | May | | | | June | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Decade | I | II | III | I-III | I | II | III | I-III | I | II | III | I-III |
| Air temperature: | | | | | | | | | | | | |
| Average | 12.9 | 14.7 | 13.5 | 13.7 | 18.3 | 18.0 | 23.4 | 19.9 | 23.5 | 26.6 | 28.2 | 26.1 |
| Maximum | 25.7 | 25.9 | 22.4 | 25.9 | 28.0 | 28.9 | 38.7 | 38.7 | 38.4 | 38.7 | 41.3 | 41.3 |
| Minimum | 2.5 | 6.3 | 4.6 | 2.5 | 10.3 | 6.4 | 9.2 | 6.4 | 13.2 | 15.4 | 15.0 | 13.2 |
| Air humidity: | | | | | | | | | | | | |
| Average relative | 55 | 61 | 63 | 60 | 59 | 43 | 56 | 56 | 44 | 34 | 37 | 38 |
| Minimum | 23 | 30 | 27 | 23 | 35 | 16 | 7 | 5 | 17 | 19 | 17 | 17 |
| Temperature on a ground surface | | | | | | | | | | | | |
| Maximum | 48 | 39 | 44 | 48 | 51 | 50 | 39 | 47 | 56 | 61 | 63 | 63 |
| Minimum | -1 | 3 | 1 | -1 | 6 | 5 | 16 | 16 | 11 | 13 | 15 | 11 |
| Temperature of the ground | | | | | | | | | | | | |
| 5 cm | 14.7 | 17.5 | 16.3 | 16.2 | 23.0 | 23.1 | 26.1 | 24.1 | 27.3 | 30.3 | 32.3 | 30.1 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 cm | 14.3 | 17.0 | 16.1 | 15.8 | 22.0 | 22.9 | 25.6 | 23.5 | 27.0 | 29.4 | 32.2 | 29.5 |
| 15 cm | 13.8 | 16.7 | 16.0 | 15.5 | 21.1 | 22.0 | 24.8 | 22.6 | 26.6 | 28.7 | 31.8 | 29.0 |
| 20 cm | 13.3 | 16.2 | 15.7 | 15.1 | 20.3 | 21.4 | 24.2 | 22.0 | 26.4 | 27.9 | 30.9 | 28.4 |
| 40 cm | 14.6 | 17.1 | 16.6 | 16.1 | 18.5 | 20.2 | 23.2 | 20.6 | 26.0 | 27.2 | 29.7 | 27.6 |
| Precipitation. mm | 18.7 | 9.1 | 16.4 | 39.2 | 1.1 | 22.6 | 0.3 | 24.0 | 3.2 | 0.0 | 5.7 | 8.9 |

| **Month** | **July** | | | | **August** | | | | **September** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Decade | I | II | III | I-III | I | II | III | I-III | I | II | III | I-III |
| Air temperature: | | | | | | | | | | | | |
| Average | 28.5 | 32.5 | 29.3 | 29.8 | 32.3 | 26.5 | 23.6 | 27.5 | 22.2 | 23.8 | 20.3 | 22.1 |
| Maximum | 36.7 | 43.7 | 37.9 | 43.7 | 45.0 | 40.9 | 39.7 | 45.0 | 33.4 | 38.4 | 32.5 | 38.4 |
| Minimum | 19.4 | 21.4 | 14.6 | 14.6 | 19.8 | 14.3 | 12.9 | 12.9 | 11.6 | 12.4 | 8.6 | 9.6 |
| Air humidity: | | | | | | | | | | | | |
| Average relative | 40 | 37 | 36 | 37 | 33 | 33 | 40 | 35 | 38 | 43 | 40 | 40 |
| Minimum | 20 | 20 | 21 | 20 | 14 | 15 | 13 | 13 | 23 | 15 | 18 | 15 |
| Temperature on a ground surface | | | | | | | | | | | | |
| Maximum | 64 | 68 | 62 | 68 | 69 | 62 | 56 | 59 | 53 | 54 | 52 | 54 |
| Minimum | 17 | 20 | 15 | 15 | 18 | 14 | 12 | 12 | 10 | 7 | 4 | 4 |
| Temperature of the ground | | | | | | | | | | | | |
| 5 cm | 33.5 | 37.2 | 33.8 | 35.1 | 36.8 | 32.4 | 29.9 | 33.0 | 27.4 | 28.0 | 25.0 | 26.8 |
| 10 cm | 33.2 | 36.7 | 33.7 | 34.8 | 35.5 | 32.4 | 30.0 | 32.6 | 27.4 | 27.8 | 25.1 | 26.8 |
| 15 cm | 33.1 | 36.3 | 33.5 | 34.5 | 35.1 | 32.2 | 30.1 | 32.5 | 27.3 | 27.8 | 25.1 | 26.7 |
| 20 cm | 32.6 | 35.6 | 33.2 | 34.0 | 34.5 | 32.2 | 30.1 | 32.3 | 27.3 | 27.5 | 25.2 | 26.7 |
| 40 cm | 31.2 | 33.8 | 32.3 | 32.5 | 33.2 | 31.7 | 29.8 | 31.6 | 27.3 | 17.4 | 25.4 | 26.7 |
| Precipitation. mm | 0.3 | 0.0 | 0.0 | 0.3 | 0.0 | 5.7 | 1.7 | 7.4 | 0.0 | 0.0 | 0.0 | 0.0 |

| **Month** | **October** | | | | **November** | | | | **December** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Decade | I | II | III | I-III | I | II | III | I-III | I | II | III | I-III |
| Air temperature: | | | | | | | | | | | | |
| Average | 19.1 | 13.0 | 11.9 | 14.7 | 9.5 | 7.1 | 3.0 | 5.7 | -6.6 | -8.0 | -3.2 | -5.9 |
| Maximum | 33.9 | 30.2 | 27.0 | 33.9 | 21.9 | 20.5 | 16.2 | 21.9 | 8.0 | -1.9 | 6.1 | 8.0 |
| Minimum | 7.9 | 1.0 | 2.0 | 1.0 | -4.0 | -4.4 | -9 | -9 | -17.4 | -16.3 | -13.6 | -17.4 |
| Air humidity: | | | | | | | | | | | | |
| Average relative | 47 | 39 | 45 | 44 | 55 | 59 | 64 | 59 | 54 | 79 | 77 | 73 |
| Minimum | 22 | 18 | 24 | 18 | 29 | 30 | 41 | 29 | 38 | 55 | 45 | 38 |
| Temperature on a ground surface | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maximum | 49 | 42 | 37 | 42 | 34 | 28 | 25 | 34 | 15 | 4 | 15 | 15 |
| Minimum | 6 | 1 | 0 | 0 | -7 | -10 | -13 | -13 | -21 | -17 | -16 | -21 |
| Temperature of the ground | | | | | | | | | | | | |
| 5 cm | 22.7 | 18.0 | 15.6 | 18.8 | 13.3 | 10.0 | 6.6 | 9.5 | -0.0 | -1.9 | 0.4 | -0.8 |
| 10 cm | 22.9 | 18.4 | 16.0 | 19.1 | 13.9 | 10.6 | 7.2 | 10.2 | 1.1 | -0.7 | 0.0 | 0.1 |
| 15 cm | 23.2 | 18.8 | 16.2 | 19.4 | 14.3 | 10.8 | 7.7 | 10.6 | 2.1 | -0.1 | 0.6 | 0.9 |
| 20 cm | 23.5 | 19.9 | 17.4 | 20.3 | 15.6 | 12.4 | 9.5 | 12.2 | 4.1 | 1.6 | 2.0 | 2.6 |
| 40 cm | 23.6 | 20.2 | 17.2 | 20.3 | 15.8 | 12.6 | 9.8 | 12.6 | 3.8 | 1.4 | 1.7 | 2.3 |
| Precipitation. mm | 6.6 | 0.0 | 0.9 | 7.5 | 0.6 | 0.0 | 0.0 | 0.6 | 6.4 | 0.0 | 0.0 | 6.4 |

## 2003

| **Month** | **January** | | | | **February** | | | | **March** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Decade | I | II | III | I-III | I | II | III | I-III | I | II | III | I-III |
| Air temperature: | | | | | | | | | | | | |
| Average | 2.6 | -2.5 | -2.7 | 0.9 | 3.4 | -1.9 | -1.9 | -0.1 | 0.2 | 5.1 | 3.0 | 4.3 |
| Maximum | 14.1 | 7.8 | 8.1 | 14.1 | 17.6 | 5.1 | 4.3 | 17.6 | 13.2 | 16.5 | 22.6 | 22.6 |
| Minimum | -6.5 | -9.4 | -13.6 | -13.6 | -4.0 | -12.5 | -8.4 | -12.3 | -10.6 | -1.2 | -1.8 | -10.6 |
| Air humidity: | | | | | | | | | | | | |
| Average relative | 80 | 79 | 79 | 79 | 78 | 71 | 67 | 72 | 58 | 74 | 65 | 66 |
| Minimum | 39 | 51 | 57 | 39 | 42 | 41 | 42 | 41 | 29 | 47 | 38 | 29 |
| Temperature on a ground surface | | | | | | | | | | | | |
| Maximum | 17 | 16 | 15 | 17 | 24 | 11 | 19 | 24 | 23 | 28 | 38 | 38 |
| Minimum | -8 | -13 | -13 | -13 | -5 | -18 | -10 | -18 | -17 | -5 | -4 | -17 |
| Temperature of the ground | | | | | | | | | | | | |
| 5 cm | 3.1 | 1.2 | 0.7 | 1.7 | 4.2 | 1.2 | 1.1 | 2.2 | 2.4 | 6.4 | 10.7 | 6.4 |
| 10 cm | 3.2 | 1.5 | 0.8 | 1.8 | 4.3 | 1.6 | 1.3 | 2.4 | 2.4 | 5.8 | 10.3 | 6.2 |
| 15 cm | 3.5 | 2.3 | 1.3 | 2.4 | 4.4 | 2.1 | 1.7 | 2.7 | 2.7 | 6.0 | 9.7 | 6.1 |
| 20 cm | 4.7 | 3.6 | 2.4 | 3.6 | 5.5 | 3.5 | 2.9 | 4.0 | 3.5 | 6.4 | 10.5 | 6.8 |
| 40 cm | 3.8 | 3.6 | 2.1 | 3.2 | 4.8 | 3.4 | 2.4 | 3.5 | 3.1 | 5.7 | 9.2 | 6.0 |
| Precipitation. mm | 0.9 | 6.4 | 3.1 | 10.4 | 5.7 | 0.7 | 5.5 | 11.9 | 0.4 | 13.4 | 4.9 | 18.7 |

| Month | April | | | | May | | | |
|---|---|---|---|---|---|---|---|---|
| Decade | I | II | III | I-III | I | II | III | I-III |
| Air temperature: | | | | | | | | |
| Average | 14.8 | 10.4 | 14.4 | 13.2 | 17.1 | 20.7 | 22.4 | 20.1 |
| Maximum | 33.7 | 25.4 | 31.7 | 33.7 | 30.7 | 33.1 | 34.6 | 34.6 |
| Minimum | 0.3 | -1.2 | 3.4 | -1.2 | 3.0 | 10.8 | 13.4 | 3.0 |
| Air humidity: | | | | | | | | |
| Average relative | 51 | 48 | 59 | 53 | 52 | 58 | 56 | 55 |
| Minimum | 26 | 22 | 28 | 22 | 26 | 28 | 30 | 26 |
| Temperature on a ground surface | | | | | | | | |
| Maximum | 50 | 44 | 47 | 50 | 51 | 51 | 54 | 54 |
| Minimum | -4 | -6 | 4 | -6 | 1 | 8 | 11 | 1 |
| Temperature of the ground | | | | | | | | |
| 5 cm | 13.4 | 13.9 | 16.0 | 14.4 | 19.6 | 23.8 | 25.1 | 22.8 |
| 10 cm | 12.9 | 13.7 | 15.6 | 14.1 | 18.7 | 22.4 | 24.7 | 21.9 |
| 15 cm | 12.2 | 13.6 | 15.1 | 13.6 | 17.9 | 21.6 | 24.4 | 21.3 |
| 20 cm | 12.7 | 14.5 | 15.5 | 14.2 | 18.2 | 21.8 | 24.7 | 21.6 |
| 40 cm | 11.8 | 14.6 | 14.8 | 13.7 | 16.8 | 19.2 | 23.1 | 19.7 |
| Precipitation. mm | 0.4 | 0.0 | 5.8 | 6.2 | 10.1 | 23.0 | 18.3 | 51.4 |