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Proposal for structure and content of the National Strategy of Turkmenistan to reduce the risks of sand and dust storms

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Table of content

List of Abbreviations

AST	Academy of Sciences of Turkmenistan
WB	World Bank
GM UNCCD	Global Mechanism of the UN Convention to Combat Desertification
GIZ	German Society for International Cooperation
GEF	Global Environmental Fund
SCWM	State Committee for Water Management
HMS	Hydrometeorological Service of Turkmenistan under the Ministry of Agriculture and Environmental Protection
SCS	State Customs Service
DAAD	German Academic Exchange Program
DARCA	Desertification and Recovery: Modeling the Impact of Market-Based Reforms on Central Asian Rangelands
ICARDA	International Center for Agricultural Research in the Dry Areas;
CALAI	Central Asia Land Administration Initiative
IFAD	International Fund for Agricultural development
UNCCD	UN Convention to Combat Desertification
CMT	Cabinet of Ministers of Turkmenistan
CDW	Collector Drainage Water
CJSC	Cloced Joint Stock Company “Turkmendokun”
ISCEP	Interdisciplinary Environmental Commission
MA&EP	Ministry of Agriculture and Environmental Protection
MOG	Ministry of Oil and Gas
ME	Ministry of Energy
MoE	Ministry of Education
MJ	Ministry of Justice
IFAS	International Fund for Saving the Aral Sea
MFA	Ministry of Foreign Affairs

MoHMI	Ministry of Health and Medical Industry
MoE	Ministry of Education
MoFE	Ministry of Finance and Economy
MoC	Ministry of Culture
NIDFF	National Institute of Deserts, Flora and Fauna
NAPCD	National Action Plan to Combat Desertification
R&D	Research and Development works
UNDP	United Nationa Development Programme
PANCT	Public Association for Nature Conservation of Turkmenistan
FSNPPS	Forest Seed and Natural Parks Protection Service
UIET	Union of Industrialists and Entrepreneurs of Turkmenistan
SRAPCD	Subregional Action Program to Combat Desertification
TAU	Turkmen Agricultural University named after S. Niyazov
FAO	UN Food and Agriculture Organization
CA	Central Asia
SSS	Main state service "Turkmenstandartlary"
SCS	State Committee for Statistics

Introduction

Program of President of Turkmenistan Gurbanguly Berdimuhamedov on socio-economic development of the country for 2019-2025 gives an important place to issues of environmental safety and environmental protection. Turkmenistan focused the attention of the world community on issues in the field of ecology and on ways to solve problems related to climate change, rational nature management, respect for water and land resources and combating desertification processes.

A global document - Paris Agreement on Climate - was adopted in December 2015 and ratified by Turkmenistan on October 21st, 2016. The global community has outlined a new Climate Agenda in the context of the adoption of Sustainable Development Goals (SDGs).

With the adoption of commitments under the Paris Agreement and the implementation of the SDGs, a new National Strategy of Turkmenistan on Climate Change was prepared in 2019. The new version of the Strategy also meets the objectives of the Program of Socio-Economic Development of Turkmenistan for the period of 2019-2025.

In 2000, Turkmenistan prepared and submitted the First National Communication on Climate Change to the UNFCCC Secretariat, in 2010 the Second National Communication was published, and in 2015 the Third National Communication became available. Currently, Turkmenistan has started preparing the Fourth National Communication on Climate Change. Turkmenistan joined the UN Convention to Combat Desertification (UNCCD) in 1996. In 1997, through the efforts of scientists and specialists, the National Action Program to Combat Desertification (NAPCD) was developed. In order to expand cooperation between our country and international structures in the field of environmental protection in various areas, to organize the fulfillment of the obligations assumed to implement the requirements of the relevant international agreements signed and approved by Turkmenistan, the President of Turkmenistan signed a Resolution, in accordance with which an **Intersectoral Commission on Protection the environment** was formed and its composition was approved.[1] At the state level, the implementation of the UNCCD is closely related to the implementation of the Program of the President of Turkmenistan for socio-economic development of Turkmenistan for the period of 2019-2025 and National Strategy of Turkmenistan on Climate Change (2019).

The information center of the Ministry of Health and Medical Industry of Turkmenistan reported in July this year that as a result of the analysis of the state of atmospheric air in the city of Ashgabat and velayats, wind and dust activity was observed due to the impact of the air flow from the south -east, northeast and north. An increased content of dust in the ambient air was registered, which is unfavorable for human health, namely for the respiratory system. In the middle of summer, in order to reduce the natural-exogenous impact due to a possible change in the composition of the air and an increase in the content of pathogens in it, employees of the health care system, retail outlets, public transport and other service workers were told to use personal protective equipment for the upper respiratory tract - medical masks. The same preventive measures should be followed by people with chronic and allergic diseases. It is advised necessary to follow the rules of personal and public hygiene, first of all, wash hands, keep the home and work environment clean.

In the material published on August 22, 2020 (“Neutral Turkmenistan” No. 212) “Priority positions of Turkmenistan at the 75th session of the UN General Assembly” it is noted: Dust and salt storms, carrying especially harmful substances from the bottom of the dried up Aral Sea, spread over thousands of kilometers and pose a real danger to human life, and have an extremely

[1] “Neutral Turkmenistan”, 24 October, 2020

negative impact on nature, climate, health of people living in the Aral Sea region and far beyond its borders.”

President of Turkmenistan Gurbanguly Berdimuhamedov, in his speeches at various forums, emphasizes that without solving this problem it is difficult to talk about the sustainable development of Central Asia. According to the head of state, the efforts of the countries of the region at the national level are clearly insufficient today and require the support of the world community; in particular, an integrated approach, active and systematic participation of the United Nations is important[2].

All the above indicates the relevance of this work. The mathematical calculation of the transfer of possible volumes of sand and dust is used to develop practical recommendations for protection of settlements and various types of engineering facilities from sand drifts and blowing out. The National Institute of Deserts, Flora and Fauna of the Ministry of Agriculture and Environmental Protection of Turkmenistan has developed and has been using an effective methodology for many years to protect against sand drifts and blowing of various types of engineering facilities built and under construction in the Karakum Desert. In addition, in practice, methods for calculating the possible volumes of sand transfer from various forms of aeolian relief are widely used. Based on the results obtained by this methodology, specific practical recommendations are being developed to prevent deflationary processes for a specific region of the Karakum Desert.

At present, the spatial and temporal distribution of the frequency of occurrence of dangerous and especially dangerous dust storms in the territory of Central Asia has been well studied. Dust storms with a duration of 3-12 hours, and storms with a wind speed of 10-14 m/s and a meteorological visibility range of 500-1000 m are considered dangerous. The most dangerous dust storms include those with the duration of 12 hours or more, with a wind speed of 15 m/sec and more, or storms regardless of the duration and speed of the wind at a meteorological visibility range of 50 m or less. A dust storm can carry millions of tons of dust over a distance of several thousand kilometers. Although this phenomenon is meteorological, it is nevertheless closely related to the state of the soil cover and topography[3].

It is necessary to carefully study and develop a strategy for the management of sand and dust storms (SDS), since insufficient tracking and underestimation of the impact on the natural structure of desert landscapes can lead to the occurrence of unfavorable ecological processes. In addition, these processes negatively affect the growth of the country's economy and the health of the population. In our opinion, in the processes of SDS, the concept of sand and dust should be distinguished, since they are different natural bodies and are not related to soil! They are transported, accumulated and deposited for completely different reasons.

[2] “Neutral Turkmenistan”, № 203. 12.08.2020

[3] N.S. Orlovsky, L. Orlovskaya, R. Induitu. Dangerous and especially dangerous dust storms in Central Asia. Arid ecosystems, 2013, volume 19, no. 4 (57), pp. 49-58

Strategy goal

The goal of the national strategy of Turkmenistan for management of sand and dust storms is long-term understanding and solution of the issues of neutralizing the impact of SDS processes and the formation of state policy of Turkmenistan to combat the consequences of their negative impact on the country's economy.

The national strategy is designed to ensure the comprehensiveness and consistency in the implementation of the state policy of Turkmenistan in challenges of countering the development of SDS processes. The strategy provides a comprehensive analysis and an assessment of the scale of coverage of the SDS processes on the territory of the country and the real threats that have arisen for the sustainable development of the economy of Turkmenistan, including the negative impact of the SDS processes on agriculture, industrial infrastructure, water management, and most importantly on the health of the country's population. The goal of the strategy is long-term planning and provision of measures to neutralize the negative impact of the SDS processes to maintain environmental stability and sustainable development of the state. The strategy will ensure a consistent transition to the use of modern methods and technologies to ensure the steady development of the country's economic sectors in the near future and will provide an understanding of the reality of the threat of development of the SDS processes, and their negative impact on the environment and the country's natural resources. In international and regional cooperation, the strategy will be the main instrument of Turkmenistan to fulfill its obligations under the UNCCD and UNFCCC conventions.

1. Development of SDS processes on the territory of Turkmenistan

1.1. Reasons for dust storms development

The sharply continental climate of deserts is characterized by long hot summers, cold winters for these latitudes, a large amplitude of daily temperatures, dry air, low cloud cover, scarcity of precipitation with its extremely uneven distribution throughout the year. In summer and early autumn, when it is dry and clear, and the earth's surface heats up greatly during the day, and at night it cools significantly, the type of daily weather is most stable and constant. Summer comes in May; the rains stop, the sky becomes cloudless, the sun heats, dust appears (7,8). The most characteristic process that determines the summer weather of deserts is the formation of continental tropical air in the area of slightly reduced pressure – “thermal depression”. Occasionally, in summer, cold intrusions of boreal air in the rear of cyclones coming from the Caspian Sea occur. These invasions are accompanied by strong winds, dust storms, shower rains, thunderstorms.

In summer, the soil heats up much more than air. For example, on May 16th in the Karakum Desert at a height of 2 m, the temperature was 33, 5°, while the soil temperature was 64°. Already in January, on the surface of the sand, the temperature can reach 47°, and in summer up to 70°. Although the heat does not spread far into the depths, fine loess dust, which forms during the usual summer rainlessness, is very easily lifted by the wind and carried away by ascending currents to the upper layers of the atmosphere, very often causing haze, from which the sky becomes whitish and the transparency of the air is greatly reduced. Dust, which creates haze in summer, is often brought in by intrusions of cold air from the north. The presence of the bulk of the dust is explained by the extreme dryness of the loess surface and the absence of vegetation. The haze sometimes lasts up to 5 days in a row, and repeats itself several times over the summer.

Since the desert air contains very little moisture, it hardly protects against solar radiation. The value of the total solar radiation averages 200-220 kcal/cm² per year, which is more than in the equatorial belt, where there is a lot of cloudiness. During the day, the sun is shining brightly over the desert and there is an incinerating heat (in the Sahara, for example, about 50 °C). At night, the earth's surface cools down quickly, and the temperature can drop to 5 °C. Thus, the daily temperature range in tropical deserts is approaching 40 °C. Strong (80-100 km/h) winds constantly blow in the desert, capturing loose material and carrying it over long distances, causing sand and dust storms. Dust from the Sahara Desert, for example, was found more than 3000 km from its place of origin, in northwestern Europe. And dust from the Australian deserts was found on the coast of the island of New Zealand, located 2400 km away from them.

The horizontal length of areas covered by dust storms is very different - from several hundred meters to thousands of kilometers or more. The vertical dustiness of the atmosphere can vary from 1–2 m (dusty or sandy drifts) to 6–7 km. Dust storms are usually observed in summer. In the southern regions, they can develop in winter, since the snow cover is very unstable here and in the absence of precipitation, the soil surface dries out quickly. In winter, in these areas, it is also possible to develop a kind of snow-sandy drifts, in which dust and sand are transferred along with dry snow. **The main reason for the formation of dust storms is turbulence due to the structure of the wind, which contributes to the rise of dust and sand particles from the earth's surface**. In this case, the degree of vertical instability of the air mass, in which a dust storm develops, is very important. Strong daytime heating of the lower air layers in summer leads to a significant increase in temperature gradients up to a height of 1-1.5 km above the steppes and up to 2-2.5 km above deserts. Convective mixing, propagating up to these heights, tends to distribute the particles of sand and dust raised from the earth's surface throughout the layer covered by it. Small particles that form haze can rise very high, while the heavier ones have a lower rise and quickly fall to the earth's surface.

With stable air stratification, as is observed, for example, in early spring in the warm sectors of the Murghab and South Caspian cyclones, the layer of surface air overheating is limited to several hundred meters. Strong dust storms are often observed here, spreading up to an altitude of 200-300 m; at high altitudes, the air remains perfectly clean. Dust storms begin at some critical values of wind speed, which depend on the terrain and soil structure and therefore are not the same for different regions. In most areas, dust storms begin at a wind speed of 10-12 m/s. The duration of dust storms varies widely - from several seconds to several days. For example, on the southern coast of the Aral Sea, a continuous dust storm lasting 80 hours was recorded. In accordance with the state of the soil and circulation conditions, both in the number of events and in the total duration, dust storms are distributed very unevenly. Within the limits of one relatively small territory, a detailed study can reveal places in which dust storms develop 4-5 times more often than in nearby regions. In the recurrence of dust storms, large differences are revealed at the boundaries between the cultivated irrigated zone and the natural semi-desert area.

The diurnal variation of dust storms (maximum - in the midday and afternoon hours, minimum - in the second, half of the night and early in the morning) corresponds to the summer diurnal variation of wind speed and the course of instability of the stratification of the lower tropospheric layers. During rather long nights, especially in spring and autumn, the underlying surface is cooled down (often to frost), which leads to condensation of water vapor and moistening of the soil surface, while the flowability of small soil particles decreases. The following main types of dust storms can be distinguished by the duration of the storm and visibility during it[4]:

1. Short-term dust storms with relatively little loss of visibility. They are caused by purely local fluctuations in wind speed and direction, their duration does not exceed 30 minutes, and visibility remains within 3-4 km, sometimes increasing to 6-10 km. Dust storms of this type are often interspersed with dusty drifts.

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[4] N.S. Orlovsky, L. Orlovskaya, R. Induitu. Dangerous and especially dangerous dust storms in Central Asia. Arid ecosystems, 2013, volume 19, no. 4 (57), pp. 49-58

2. Short-term dust storms with severe deterioration of visibility. They are similar in duration to storms of the first type, but cause a significant deterioration in visibility (up to several hundred meters, and sometimes up to 10-20 m); begin almost suddenly - in relatively calm weather, the wind speed increases sharply, and at the same time dust clouds of various vertical strengths sweep along. After the first sudden deterioration in visibility, it gradually increases to 1–2 km or more, although the wind speed often continues to increase. These storms are usually generated by squall winds associated with the passage of thunderstorms or sharp cold fronts of the second kind. A sign of the approach of such a dust storm is a gray dust curtain under the cumulonimbus clouds, when they are still near the horizon, within sight.

3. Long and pulsating dust storms with a predominance of relatively slight deterioration in visibility (2-4 km). Periodically, there is a short-term improvement, then a deterioration in visibility. Fluctuations in visibility occur over a wide area, in different places and at different times. The duration of dust storms of this type reaches several hours or even days. These storms occur in conditions of stable baric field with large baric gradients (southeastern, southern and southwestern periphery of powerful inactive anticyclones).

4. Long and strong dust storms with a decrease in visibility to 500-1000 m, in the initial stage - to several tens of meters. Dust storms of this type are usually of great horizontal and vertical extent and are characterized in all directions by a uniform, usually dark gray background. Fluctuations in visibility occur against an overall background of low visibility values. The duration of such a storm is not less than 2-4 hours.

5. Dusty or sandy drift - transfer of dust or sand in a layer no more than 2 m above the soil surface. Dusty drifts, as a rule, are short-lived and as an independent phenomenon are observed relatively rarely; most often they occur early during a dusty storm or at the end of it. Sandy drifts are a very common occurrence in deserts, especially when there is coarse-grained, well-ventilated sand on the soil surface. In some deserts in summer, sandy drift is observed almost daily, and its height is mainly limited to the lower half-meter layer. Such drifts cause significant sand blocks of roads, fields, canals, etc. In the cold half of the year, sandy drifts can be combined with dust and sand storms of the third type, this usually occurs on the southern periphery of inactive extensive anticyclones at wind speeds of about 15 m/s or more. Drifting snow is characterized by a smoother structure of the wind field and often stable stratification of air masses. The continuous penetration of cold air through numerous gorges and even its overflow through the entire low ridge creates a long-existing orographic conditioned storm zone. This explains the increased frequency of dust storms in narrowing mountain valleys and gorges (dust storms in Kokand, in the throat of the Fergana Valley, in the upper reaches of the Amu Darya, etc.). The same reason contributes to the high stability of the zone with dust storms in the foothills of the Kopetdag, in the North Caucasus and in other regions, where the winds at the periphery of the anticyclone increase due to the orographic thickening of isobars and isotherms near mountain ranges.

The blowing and blowing of the smallest particles of soil or sand in deserts is called deflation[5]. In this case, the particles are transported hundreds or even thousands of kilometers. The wind penetrates in deserts into all cracks in rocks and carries out weathered, loose material from there. The sand, thrown with force on the rocks by wind, gradually grinds them. If they are composed of rocks of varying strength, they become rocks of bizarre shapes with cornices of harder rocks and blowing niches in softer rocks. Grinding, abrasion, filing and drilling of rocks by moving masses of debris moved by the wind (as well as water, ice, etc.) is called corrosion. Wind-blown sand produces especially great work in the lowest, surface layers of the air stream. This is how rocks - remnants on relatively thin support legs appear; rocks of heterogeneous strength form

[5] Zonn I.S., Nikolaev V.N. *et al.* Experience of combating desertification in the USSR. Moscow. Publishing house “Mysl”, 1981.

a cellular structure resembling a honeycomb. Where the wind dies down, the particles carried by it accumulate. Aeolian deposits are formed over large areas (aeolian loesses, sands of dunes, etc.). Aeolian sands are blown deposits of rivers, seas, lakes and products of physical weathering. Lighter, dusty particles are carried away by the wind to the outskirts of deserts and further to the steppe regions and mountain slopes. Accumulating, they form loess - a non-layered, fine-grained, porous rock of light yellow (fawn) color, consisting of particles of the finest dust, clay and sand (quartz) with a significant content of calcium carbonate, with voids - the passages of worms, earth-moving animals and dead plant roots. Loess is easily rubbed with fingers and is able to hold vertical walls in outcrops. Nutrient-rich loesses can serve as base for development of fertile soils, such as black soil. Dune chains in the desert, unsecured by vegetation, can be moved by the wind at a speed of tens of centimeters to hundreds of meters per year.

1.2. Development of SDS processes depending on the wind regime of the territory

An effective methodology developed at the National Institute of Deserts, Flora and Fauna was used in order to study the typical wind regime of the territory of Turkmenistan, which allows, by sampling the speed and direction of the wind by 16 points, to calculate the volume of transfer of sand and dust[6]. Long-term indicators of wind speed and direction (10 years) are taken as a basis. Long-term data on meteorological stations were selected and processed: Bokurdak, Karrykul, Dashoguz, Erbent, Darvaza, Shahsenem, Turkmenabat, Repetek, Uch-Adji, Aydin and Dzhebel, which cover the entire territory of Turkmenistan[7].

According to the Bokurdak meteorological station, the average long-term number of cases of active winds per year is 403. The prevailing direction of winds during the year is east (96 cases with an average annual speed of 6.0 m/s according to long-term data), which is 23.9% of the number of cases of active winds. They are followed by ESE and NW winds in activity, having 61 and 59 cases respectively, at a speed of 6.5 m / s and 6.6 m / s, which make up 15.1 and 14.8% of all cases, respectively. Wind activity in these directions is manifested throughout the year, but a clearly pronounced maximum occurs in the spring-summer period. From the western points, it is necessary to single out the W and WNW winds, which amount to 47 and 41 cases at a speed of 6.4 m/s and 6.5 m/s, which is, respectively, 11.7 and 10.1% of all cases. They are active from February to July.

According to the Karrykul meteorological station, 616 cases of active winds are observed per year. The winds of the eastern points prevail here. The share of B (eastern) directions accounts for 150 cases at a speed of 6.5 m/s, which is 24.4% of the number of cases of active winds per year. It is followed in terms of activity by ESE (100 cases at 6.6 m/s) and NW (97 cases at 6.7 m/s) winds, having 16.3% and 15.7%, respectively. The winds of these points are active throughout the year. Other winds include WNW (l4.5%) and ENE (7.6%) directions. The average speeds of these winds are 6.5 m/s and 5.7 m/s, respectively. The maximum wind speeds in these directions reach 12 m/s, 12 m/s, 18 m/s, 14 m/s and 12 m/s.

At the Dashoguz meteorological station, on average, 1141 cases of active winds are observed per year. The prevailing of them are B winds (195 cases at a speed of 6.6 m/s) direction - 17.1% of the number of active winds per year. They are followed in activity by the C winds (117 cases at a speed of 6.1 m/s) and ENE (104 cases at a speed of 6.5 m/s) directions, accounting for 10.1% and 9.1%, respectively. Wind activity in these directions is manifested throughout the year.

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[6] Veisov S.K., Ivanov A.P., Khamraev G.O., Akyniyazov A.D., Ataev Kh. Calculation of the transfer of possible volumes of sand from aeolian landforms. A., 2013.

[7] Veisov S.K., Khamraev G.O., Annaeva G.N. Methods for the design and protection of linear engineering facilities in the Karakum Desert // Problems of Desert Development, 2007, no. 3.
Veisov S.K., Khamraev G.O., Dobrin A.L. Development of processes of technogenic desertification in the territory of Turkmenistan and combatting against them. - Almaty, 2008

Among other winds, SWE (96 cases at a speed of 6.0 m/s) and NE (94 cases at a speed of 6.1 m/s) directions can be noted, accounting for 8.4% and 8.2% of the number of cases per year, respectively. ... Thus, each considered meteorological station is characterized by a large difference in the wind regime.

Each meteorological station has its own dominant wind directions. From north to south, a slight decrease in the frequency and average wind speeds is noted. At all the considered meteorological stations, the western and eastern points have a dominant direction.

For Bokurdak and Karrykul meteorological stations, a large influence of the winds of the western, north-western and eastern directions is noted, and in Dashoguz - northern, western and eastern wind directions are observed.

According to Erbent meteorological station, the average long-term number of active winds per year is 321. The prevailing winds are western and eastern, among which there are W and E directions (60 and 59 cases at an average annual speed of 6.2 m/s and 5.6 m/s), having, respectively, 19.0% and 18.7% of the number of cases per year, blowing in the period from February to June. The next most active WNW winds (41 cases at a speed of 5.9 m/s), which is 12.9% of the number of cases per year. They are active from March to July. The share of NW winds is less than the previous 33 cases at a speed of 5.9 m/s), which is 10.3%. The period of their activity coincides in time with the ZSZ direction.

According to the Darvaza meteorological station, 846 cases of active winds are observed per year. The winds of the eastern half of the horizon prevail here. B direction accounts for (118 cases at a speed of 5.8 m / s), i.e. 13.9% of the number of cases of active winds per year. Next in terms of activity are the W winds (109 cases at 6.8 m / s) and NE (94 cases at 5.8 m / s). Directions, respectively, account for 12.8% and 11.0% - of the total number of cases. The winds of these points are active throughout the year, but have a pronounced maximum in the winter-spring period (December-May). Other winds include ENE (90 cases at 6.3 m / s) and WNW (74 cases at 6.4 m / s) directions, which are 10.6% and 8.8%, respectively. The maximum wind speeds in these directions reach, respectively, 8 m/s, 13, m/s, 11 m/s, 12 m/s, 10 m/s.

According to the Shahsenem meteorological station, 646 cases of active winds are observed per year. East winds prevail here. The share of B direction (95 cases at a speed of 5.8 m/s) accounts for 14.8% of the number of cases of active winds per year. Next in terms of activity are winds of ENE (82 cases at 6.2 m/s), NE (76 cases at a speed of 6.0 m/s), W (75 cases at a speed of 6.4 m/s), SWE (72 cases at a speed of 6.3 m/s) directions, accounting for 12.7%, 11.8%, 11.6%, 11.2%, respectively, of the total number of cases per year. The winds of these points are active throughout the year, but have a pronounced maximum in the winter-spring-summer period (March-August). The maximum wind speeds in these directions reach values of 12 m/s, 11 m/s, 15 m/s, 12 m/s, respectively.

An analysis of the wind regime of the Darvaza and Shahsenem meteorological stations shows that for both regions the winds of the western and eastern points are the most dangerous. But for Darvaza region, the indicated directions are supplemented by N, NNE, NE and NNW, NW directions, which make up 28% of the total number of wind frequency cases, which should be taken into account when planning and carrying out sand-strengthening works in the Darvaza region.

Weather station Turkmenabat. The average long-term number of cases of active winds per year is 877. Winds from NE, N, SE, and SE directions dominate, having an average speed of 6.2 m/s, 5.9 m/s, 6.9 m/s, 6.8 m/s, respectively. The frequency of recurrence of winds in these directions from the winds of all directions is 22.0; 21.2; 18.7; 9.4. Moreover, the first two directions are most active in the warm season (April-October), and the rest in the winter

(November-March). The rest of the directions account for less than 30% of repeatability at average speeds from 5.5 to 6.8 m/s.

Weather station Repetek. The average long-term number of active winds per year is 349. In the cold period, the SE and SE winds dominate, accounting for 23.7% and 11.6% of all cases, respectively. The average annual speed of the SE winds is 6.7 m/s, and the SE winds are 7.8 m/s. In summer, winds from the northern half of the horizon prevail. Of these, C wind stands out - 37% of cases, with an average annual speed of 6 m/s, NW wind - 22% of cases, with an average annual speed of 6.5 m/s.

Meteorological station Uch-Adji. During the observation period, the average annual number of active winds is 327 cases. Here, in the cold period, winds from the SE direction also dominate, their share is 20.1%. Their average speed is 6.9 m/s. The SE winds are followed by B - 9.4% repeatability at a speed of 5.9 m/s and SE - 8.5% repeatability at a speed of 6.4 m/s. In the warm season, the winds of the northern directions prevail. The frequency of NNE, NW and NW winds is approximately the same and is in the range of 15.3-15.8%. NW winds reach a speed of 6.5 m/s. The speed of the rest is approximately the same - 5.9 m/s.

Meteorological station Aydin. The station is located southeast of the foot of the Big Balkhan. There, the average long-term number of cases of active winds per year is 801.8, and the average annual multi-year wind speed is 7.0 m/s. The prevailing direction of winds throughout the year is northeast. They amount to 442 cases (with an average annual speed of 8.8 m/s according to long-term data), i.e. 56% of the total number of active winds. They are followed by SW, ENE and E winds, respectively, having 117, 67 and 54 cases at a speed of 7.0 m/s; 8.5 m/s and 7.5 m/s, which are, respectively, 14.9; 8.4 and 6.8% of all cases. Consequently, for the Aydin meteorological station, winds of two main directions are characteristic: north-east and south-west. The prevailing winds are northeasterly, they dominate throughout the year, but they are sharply expressed in the winter months with a maximum in December - 65 cases.

Jebel Meteorological Station. The station is located southwest of the foot of the Big Balkhan. For this station, the average long-term number of cases of active winds per year is 358.9, and the wind speed is 6.4 m/s. The prevailing winds are northern and northwestern points. Thus, the average number of active north winds is 68 cases per year, with an average long-term speed of 6.9 m/s. These winds represent 19% of the total. They are followed by NW and NW winds with 37 and 29 cases, respectively, at a speed of 6.8 m/s and 6.9 m/s, which is 10% and 8% of the total. These winds are active throughout the year, with peak intensity in summer and early autumn. The second dominant direction is: south and southeast directions. On average, southerly winds account for 44 cases, with an average speed of 6.4 m/s, which is 12% of the total number of cases. The SE and SE rumbas account for 40 and 34 cases, respectively, with average speeds of 6.7 m/s and 6.3 m/s, respectively. In percentage terms, this is 11% and 9%. They are most active in late spring - early summer.

The result of the analysis is the following summary table 1 of the transport volumes of sand and dust by meteorological stations in Turkmenistan. In other words, the real mechanism of transport of sand and dust throughout the entire climatic year is shown based on the processing of long-term data on the speed and direction of winds.

In addition, Figure 1 shows the total transport of sand and dust across the regions of Turkmenistan. Figure 2 shows the location of the above weather stations.

1.3. The volume of transport of sand and dust (in Q m3/m*year) by weather stations of the country.

Analysis of the transport volumes of sand and dust (in Q m3 / m*year) by weather stations of the country. Table 1.

№	Name of station	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total annual volume
1	Bahardok	0,5	0,4	0,8	1,2	6,1	3,9	1,0	0,2	0,1	0,1	0,1	0,1	3,0	2,6	3,8	1,8	25,7
2	Karrykul	0,6	0,7	1,5	2,8	9,1	6,0	0,8	0,1	0,1	0,1	0,1	0,2	1,9	5,4	5,8	2,2	37,4
3	Dashoguz	11,0	9,0	8,8	9,7	18,3	8,0	4,3	2,0	1,8	1,9	3,1	3,9	8,0	4,8	5,8	6,6	107,0
4	Erbent	0,5	0,2	0,9	0,5	2,0	0,9	0,5	0,1	0,1	0,1	0,1	0,4	2,1	1,6	1,1	0,3	11,4
5	Darvaza	3,9	4,0	5,7	5,4	7,1	3,5	2,0	0,8	0,5	0,4	0,5	1,3	6,6	4,5	2,5	2,4	51,1
6	Shahsenem	3,8	4,6	4,8	5,2	6,1	1,8	0,6	0,4	0,8	0,6	0,9	1,5	4,8	1,7	2,2	1,3	41,1
7	Turkmenabat	5,1	7,0	1,4	0,35	0,38	1,82	5,1	4,18	4,46	0,83	0,82	0,78	2,23	2,85	4,76	3,5	45,91
8	Repetek	4,37	0,97	0,62	0,54	0,28	0,22	4,4	3,64	1,48	0,16	0,40	0,27	2,68	0,90	4,36	1,98	20,27
9	Uch-Adji	0,86	1,03	0,82	0,28	1,14	1,47	4,0	0,35	0,67	1,23	1,04	1,07	1,64	1,12	3,2	0,98	20,9
10	Aydin	0,7	2,2	71,7	10,8	8,7	-	0,1	-	0,4	2,2	19,0	4,9	6,6	0,1	0,3	0,1	127,8
11	Jebel	5,6	1,3	1,0	0,2	0,3	0,3	2,8	3,3	3,6	0,9	1,2	0,8	1,8	1,2	3,0	2,4	29,7

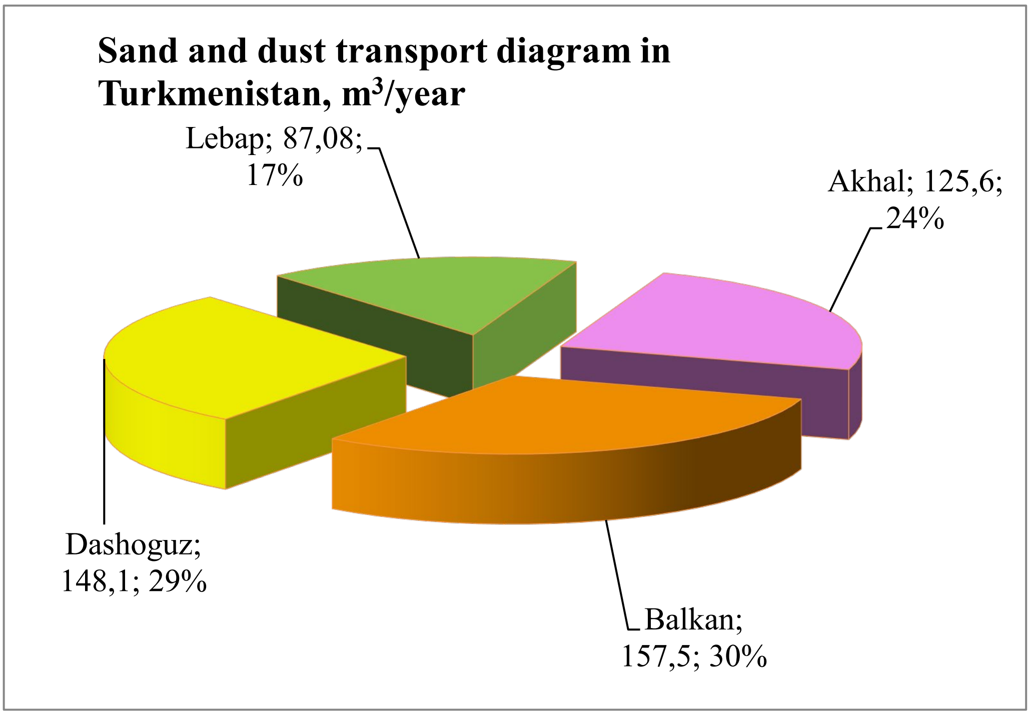

Fig. 1. Total transport of sand and dust by regions of Turkmenistan

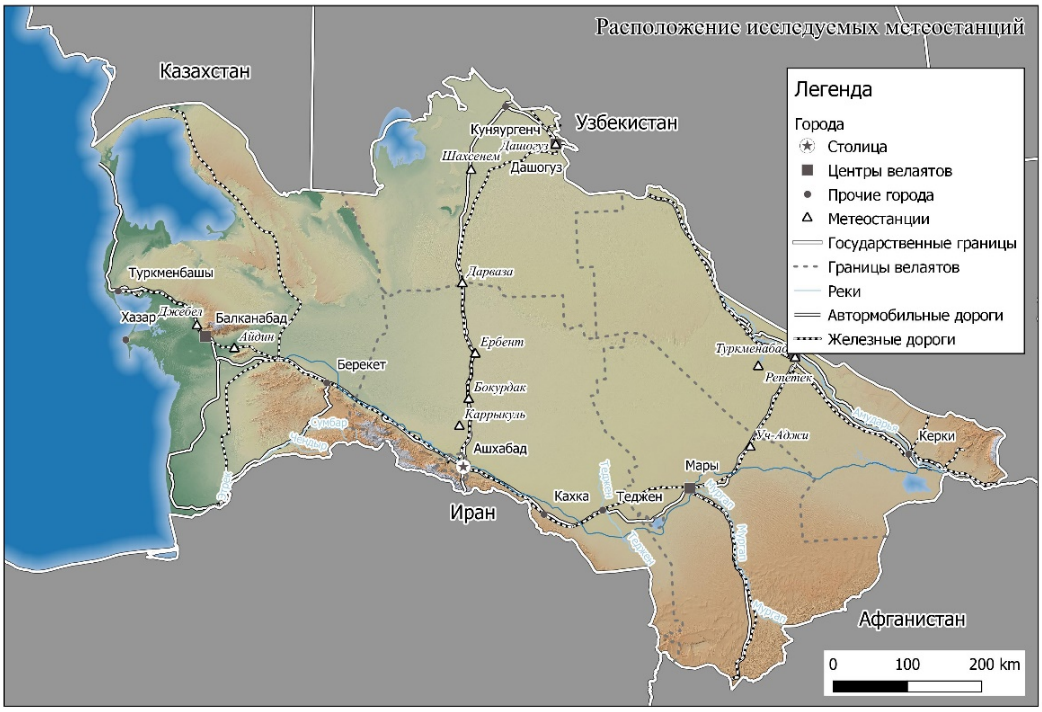

Fig. 2. Location of weather stations in the country.

To analyze the process of transfer and accumulation of SDS in Turkmenistan, national data on sources of desertification are used [8] along with places of accumulation of sand and dust in

[8] Nechaeva N.T., Fedoseev A.P. Prospects for phytomeliorative measures in the deserts of Turkmenistan in connection with natural conditions // Izvestiya AN TSSR, biol. scienc, 1965, no. 6

Turkmenistan, as well as the direction of the wind[9]. Below is the seasonal character of transport for January (winter, Fig. 3) and July (summer, Fig. 4). Desertification areas were classified as anthropogenic (formed during the development of oil fields, gas fields, and during the construction of railways), and natural (water erosion, wind erosion and soil salinization) and mixed. These maps provide information on potential desert storms and areas of accumulation of sand and dust, as well as the seasonal nature of the potential distribution of sand and dust. 17.9% of the territory of Turkmenistan is potentially subject to desertification, of which 9.9% of the territory is subject to anthropogenic desertification, 7.4% of the territory is subject to natural desertification and 0.6% of the territory is subject to mixed desertification. Pastures of the loess hilly desert, as well as a combination of pastures of sandy and loess hilly deserts (2.0% of the territory of Turkmenistan) were selected as places for the accumulation of sand and dust.

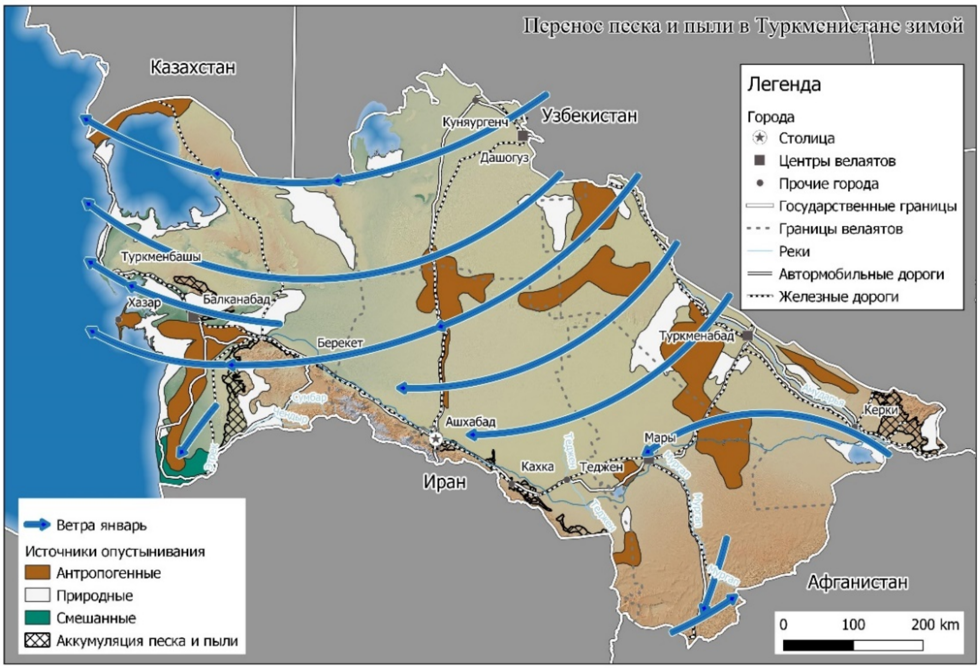

Figure 3. Winter transport of sand and dust in Turkmenistan.

[9] Scientific and Applied Reference Book on the Climate of the USSR. Series 3. Long-term data. Part 1-6, issue 36. Turkmen SSR. L .: Gidrometeizdat, 1984

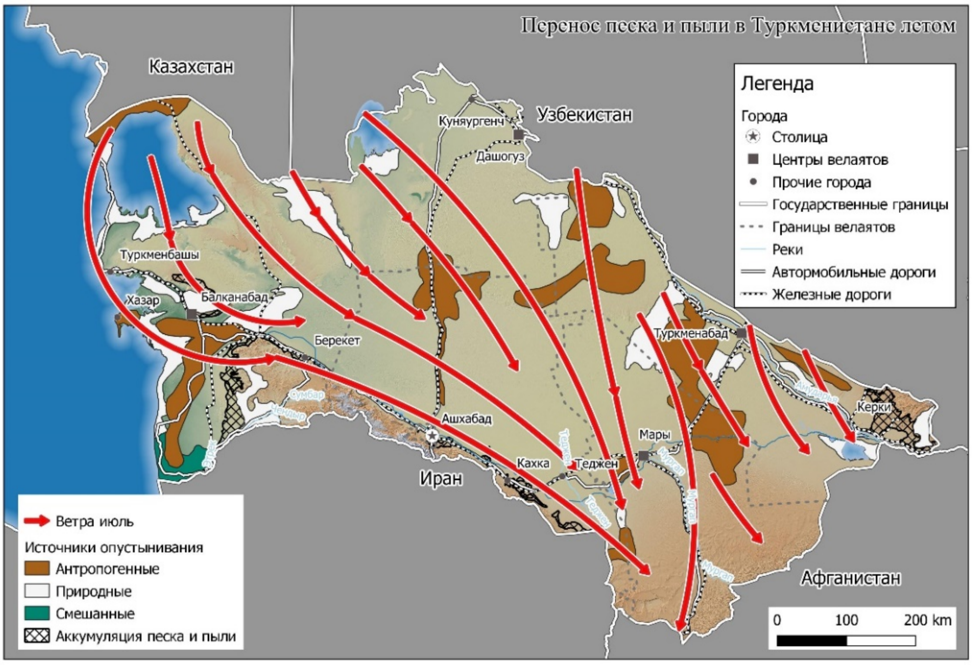

Figure 4. Summer transport of sand and dust in Turkmenistan.

Figure 5 shows the accumulation of sand and dust on the territory of Turkmenistan, which is an interpretation of the Global Map of Desert and Sand Storms. This map shows that sand and dust are mainly accumulated in the foothill plain of Turkmenistan in the southern part of the country. Figure 6 shows the percentage of the territory of Turkmenistan in terms of the degree of development of the processes of formation of SDS. It can be seen from the figure that most of the territory of Turkmenistan (68.67%) is subject to an average degree of development of the processes of formation of SDS.

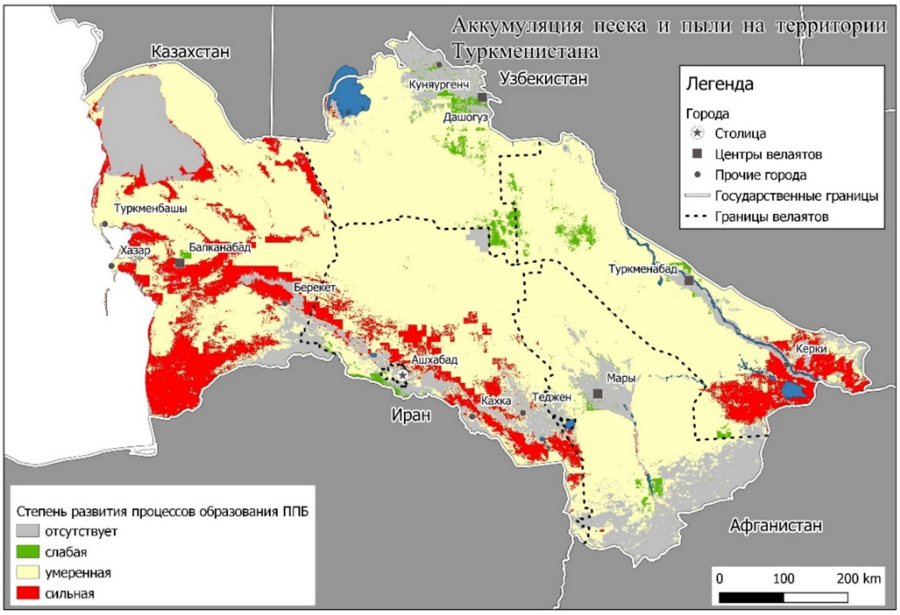

Figure 5. Accumulation of sand and dust on the territory of Turkmenistan.

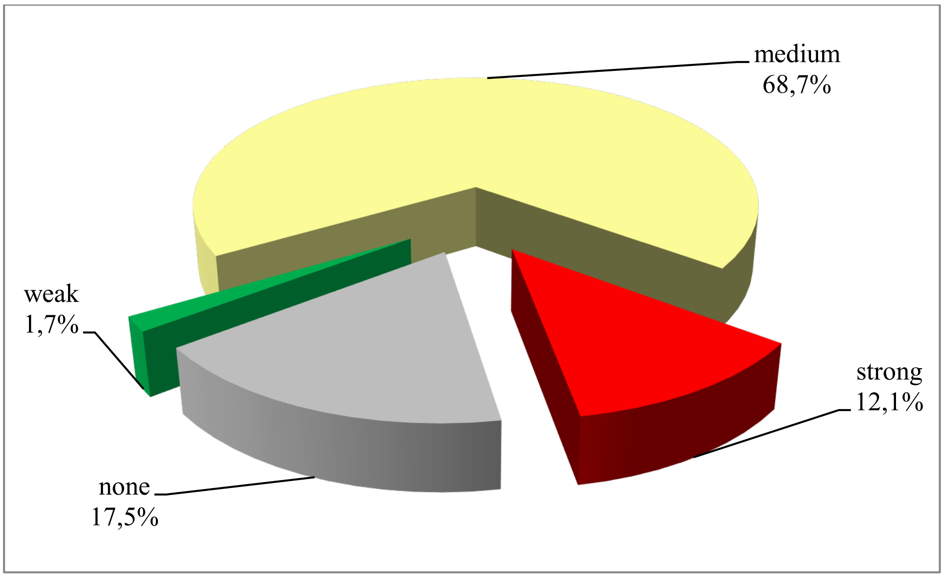

Figure 6. Territory of Turkmenistan subject to SDS processes.

To analyze the spatial and temporal distribution of dust storms on the territory of Turkmenistan, the number of days with dangerous and especially dangerous dust storms was studied [10] and on the basis of these data, an assessment of the degree of risk of dust storms was carried out. The assessment revealed that the most vulnerable regions are the Central Karakum and the western part of Turkmenistan (Figure 7).

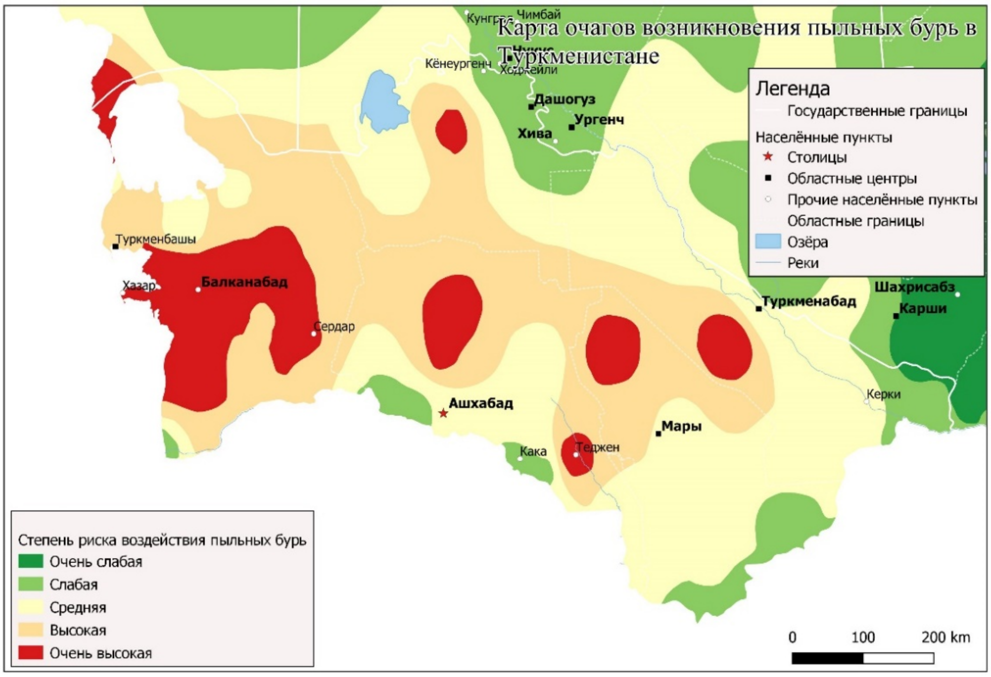

Figure 7. Map of foci of dust storms in Turkmenistan.

[10] Gupta A., Gupta A. Environmental challenges in Aral Sea basin: Impact on Human health. Int. J. Res. Soc. Sci. 2016; 6:419–440. [Google Scholar

2. The negative impact of sand dust storms (SDS) on the national economy of Turkmenistan

2.1. Impact of SDS on agriculture, water management and the environment

The impact of the SDS on the country's economy should include an economic assessment of the negative impact of the SDS on infrastructure and transport, which will show the degree of danger of their development on the territory of Turkmenistan. In addition, this assessment will show the presence of real damage, including in the design of infrastructure facilities, linear engineering facilities - roads and railways, gas transmission lines, etc. An environmental assessment of the project must be carried out without fail, and if the project does not provide for measures to ensure environmental safety (sand-strengthening work, especially at the construction sites of roads, gas pipelines, power lines, as well as places where minerals are mined), then such project will not be approved, and will not be funded.

The new National Strategy of Turkmenistan on Climate Change (2019), in the issue of adaptation of soil and land resources to climate change, provides for measures to conduct a comprehensive inventory of soil and land resources; to combat soil salinization, pasture degradation and desertification. Within the framework of the National Program of Socio-Economic Development of Turkmenistan for the period 2011-2030. measures are envisaged to combat desertification, prevent land degradation, which guarantees the social and economic well-being of the population and contributes to the rational use of natural resources.

It is necessary to note the types of socio-economic damage that are associated with the consequences of dust storms. Short-term costs include diseases in livestock, reduced crop yields, damage to engineering infrastructure, and reduced transport efficiency. Economic losses from a single storm can amount to hundreds of millions of dollars. Longer-term costs include soil erosion, ecosystem pollution, chronic debilitating health problems and desertification[11].

Surface dust deposits have a significant negative impact on agriculture, which is expressed in a decrease in crop yields due to the fact that seedlings are covered with a layer of dust, which leads to the loss of plant tissue, a decrease in photosynthetic activity and an increase in soil erosion. Ultimately, the income of the population engaged in agriculture significantly decreases and, accordingly, the standard of living decreases.

Dust deposition impacts are also reflected in indirect damage:

- sand drift of irrigation canals;
- coverage of transport routes;
- deterioration of surface water quality;
- reduced visibility due to airborne dust affecting air and ground transport.
- reduction of the output power of solar power plants,
- diseases of the respiratory tract, cardiovascular system, skin and eyes[12].

In agriculture, the damage estimate is based on data on yield losses for all crops, damage from decreased cotton yield due to secondary salinization only equals US $ 112,713,700. The costs of construction of the CDS and capital leaching of land are expressed in the amount of 64,727,900 US dollars. The total economic damage from desertification (including the cost of reforestation

[11] Sand and dust storms: overcoming the consequences of a global phenomenon.
[12] https://wedocs.unep.org/bitstream/handle/20.500.11822/22267/Frontiers_2017_CH4_RU.pdf. https://public.wmo.int/ru

and consolidation of mobile sands) is estimated at $ 346,875,800 annually.[13]. The share of agricultural sector in total GDP of Turkmenistan is more than 10% (2017), or 14,742,000,000 manats. With the gross value of agricultural products in 2017 at the level of 20,390,700,000 manats (5,829,000,000 dollars), the loss of even 15% of the cost of agricultural products will be expressed in the amount of 3,058,600,000 manats, or 873,900,000 US dollars. Actions carried out within the framework of national development programs are aimed at restoring degraded lands and natural pastures, increasing knowledge about various processes of desertification and combating it, as well as conducting regular monitoring and assessment of the development of desertification and increasing drought.

The development of desert animal husbandry is influenced by the productivity of the desert pastures of the Karakum Desert. The total area of pastures in Turkmenistan is 38.2 million hectares, i.e. almost 80% of the country's territory is occupied by desert pastures. According to the classification of N.T. Nechaeva and V.N. Nikolaev[14], on the basis of soil characteristics within the plains of Turkmenistan, the following classes of natural pastures are distinguished: sandy, gypsum, clayey and loess. The pastures of the sandy desert in the lowland part of Turkmenistan occupy a large territory, the total area of which is about 26 million hectares. The average annual reserves of feed on the pastures of the sandy desert are relatively small and amount to 0.7-1.6 centners/ha[15]. Natural pastures are the main source of feed for sheep and camel breeding throughout the year. The activities of these main livestock sectors of the country largely depend on the condition and productivity of pasture lands. Currently, more than 17 million sheep and goats, 123.2 thousand camels are grazed on the pastures of Turkmenistan[16]. In the structure of agricultural land, the area of pastures in Turkmenistan is 95.7% (38.2 million hectares), irrigated land is 4.0%, hayfields are 0.2%, fallow lands, perennial plantations are 0.2%. Improvement of pastures is an important reserve for a full year-round supply of animals with fodder and an increase in their livestock.

According to the State Statistics Committee of Turkmenistan, the total volume of investments aimed at measures for the protection and rational use of natural resources amounted to 35.5 million manats (2017), and in 2018 - 19.4 million manats (Fig. 8). and Fig. 9). It should be noted that a significant part of these funds (20.7% in 2017 and 44.8% in 2018) is aimed at the protection and rational use of water resources. At the same time, if in 2017 69.3% of the total amount was allocated for the protection and rational use of land resources, then in 2018 - only 8.2%.

[13] Land degradation in Central Asia. http://91.203.172.86/bk/water_land_resources_use/russian_ver/pdf/15.pdf
[14] Nechaeva N.T., Nikolaev V.N. On the question of the classification of pastures // Izv. AN TSSR. 1958. №3
[15] Nechaeva N.T., Nikolaev V.N. Map of pastures of Turkmenistan. - Ashgabat: АНТССР и МСХ ТССР, 1975
[16] Annamukhamedov O., Khanchaev Kh., Kepbanov Y., Veisov S.K., Shadurdyev A. Natural pastures and development of distant-pasture animal husbandry in Turkmenistan. Ashgabat. 2014

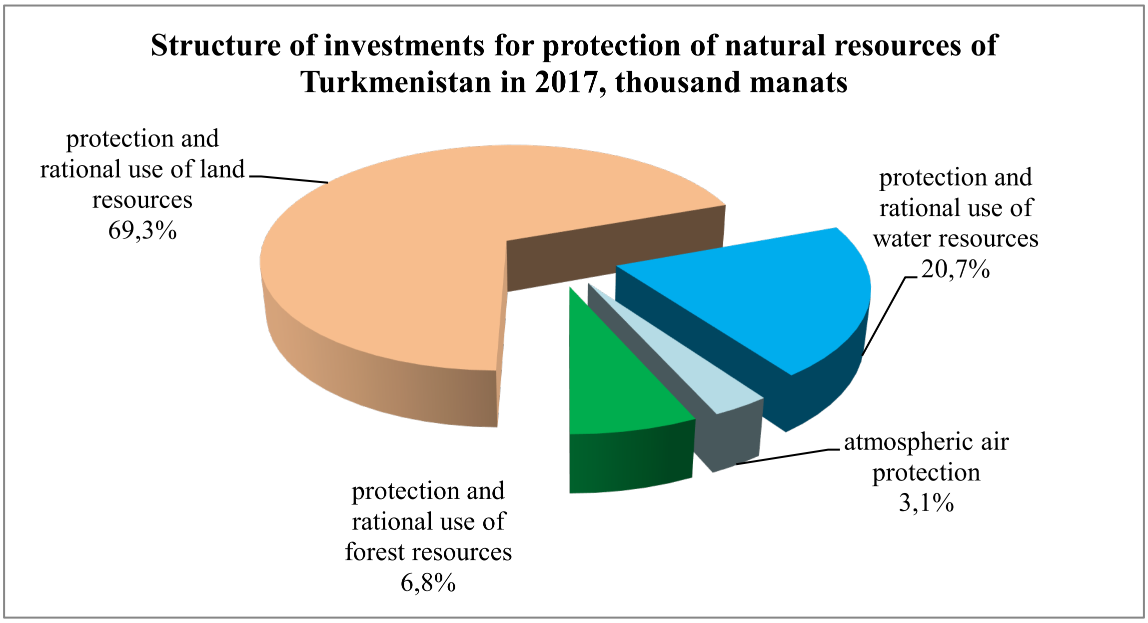

Fig. 8. Structure of investments for protection of natural resources in 2017.

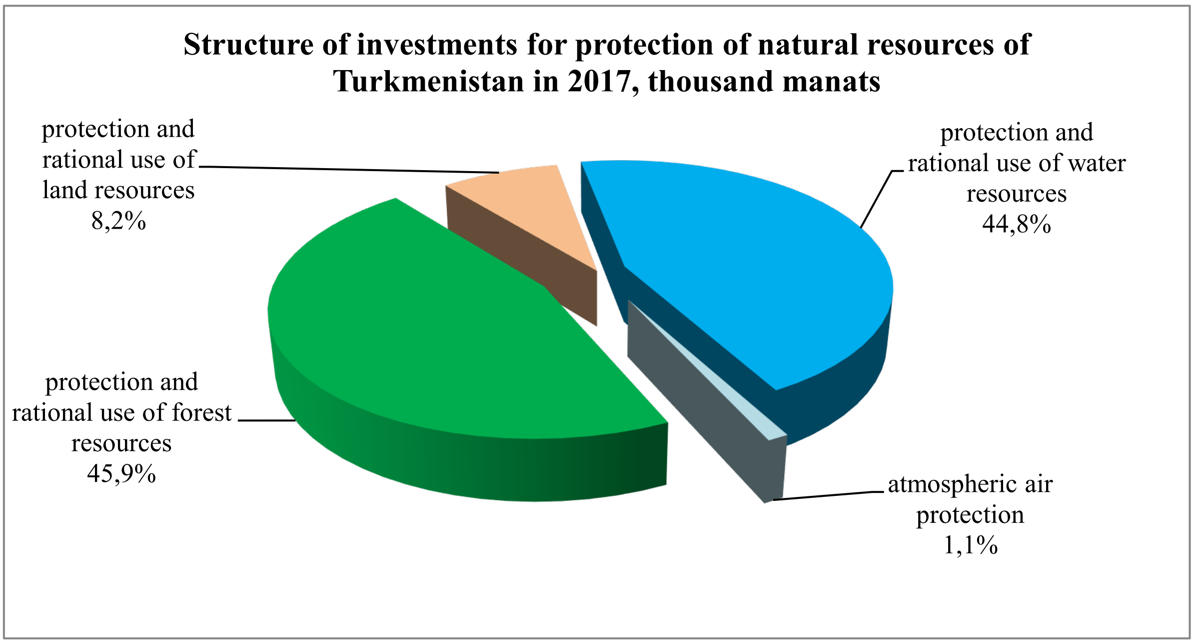

Fig. 9. Structure of investments for protection of natural resources in 2018.

2.2. Impact of SDS processes on the health of the population of Turkmenistan

Air pollution is one of the major health risks associated with the environment[17]. Airborne dust is a serious health hazard. The air contains a variety of chemical pollutants: particulate matter (dust aerosols), liquid (acid precipitation) and gaseous (vapors), which can pose a serious threat to human health[18]. The key factor determining potential hazard to human health is the size of the

[17] Sand and dust storms. https://public.wmo.int/ru

[18] Health effects of particulate matter. Implications for Policy Development in Eastern Europe, the Caucasus and Central Asia https://www.euro.who.int/__data/assets/pdf_file/0006/189051/Health-effects-of-particulate-matter-final-Eng.pdf?ua=1https://www.euro.who.int/__data/assets/pdf_file/0006/189051/Health-effects-of-particulate-matter-final-Eng.pdf?ua=1.

dust particles. The sharply continental climate of Turkmenistan increases the risks of SDS and, as a consequence, an increase in the amount of dust particles in the air. Studies have shown that each cubic meter of air contains more than 300-400 mg of dust particles. Suspended particulate matter (PM) is a widespread air pollutant comprising a mixture of solid and liquid particles suspended in air. Metrics that are commonly used to characterize PM and are relevant to health include the mass concentration of particles with a diameter of less than 10 μm (PM10) and particles with a diameter of less than 2.5 μm (PM2.5). PM2.5, often referred to as fine particulate matter, also includes ultrafine particles less than 0.1 microns in diameter. PMs with a diameter of 0.1 μm to 1 μm can remain in atmospheric air for many days and weeks and, accordingly, be subject to long-range transboundary air transport. Fine dust particles can carry with them a wide range of pollutants, spores, bacteria, viruses, fungi and allergens. After detachment from the surface, dust particles rise to higher levels of the sphere, can be carried by winds for many kilometers from the source and cause diseases of various organs and systems in humans. Groups of people with lung or heart disease, as well as the elderly and children are particularly vulnerable. The greatest attention should be paid to prevention of diseases in regions with a high average annual frequency of dust storms in all regions of Turkmenistan, especially in the children's segment.

To reduce the incidence of infectious diseases and non-infectious diseases resulting from the inhalation of PM due to TB in the territory of Turkmenistan, which today cause serious concern to all mankind, health institutions should carry out comprehensive work in accordance with WHO recommendations. And first of all, this work begins with explanatory sanitary and educational work with the population, which shows and explains to the population the seriousness and danger of diseases transmitted by SDS and the need to follow the recommendations[19]. Pregnant women who are exposed to air pollution are more likely to give birth prematurely or have low birth weight babies. Air pollution can also affect neurological development and cognitive ability and trigger the development of asthma and cancer in childhood. Children who have been exposed to high levels of air pollution may be at increased risk of developing chronic diseases such as cardiovascular disease later in life. One of the reasons children are particularly vulnerable to air pollution is the fact that they breathe more often than adults and therefore absorb more pollutants. They are also closer to the ground, where some pollutants reach their maximum concentration levels - during the development of their brains and bodies[20].

Also, exposure to PM negatively affects lung development in children, leading, in particular, to reversible pulmonary dysfunctions, as well as chronic slower lung growth and long-term pulmonary failure.[21]. Inhalation of dust particles can cause many serious noncommunicable diseases (NCDs) of the respiratory system, cardiovascular system, cancer, and premature death. Dust can cause eye and skin diseases, as well as infectious diseases such as meningitis and others. Dust can also be a provoking factor in the exacerbation of other existing chronic diseases.

Dust can also transmit infectious diseases, such as meningococcal meningitis (a bacterial infection of the thin tissue layer that surrounds the brain and spinal cord), which can lead to brain damage and death in 50% of cases if left untreated. Inhalation of dust from plant fibers, including cotton, which is grown in all regions of Turkmenistan, develops a disease called byssinosis, in which bronchospastic and asthmatic symptoms are observed[22]. Exposure to PM 2.5 reduces the life expectancy of the region's population by an average of about 8.6 months. There is no evidence to support any safe exposure level or threshold below which no adverse health effects occur. The exposure can be exposed anywhere, and it does not depend on the desire or unwillingness of people, in connection with which its importance as a determinant of health increases even more.

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[19] https://sustainable development.un.org/content/documents/23315Turkmenistan_VNR_2019.pdf, https://turkmenistan.un.org/index.php/ru/42790-otchet-po-ramochnoy-programme-partnerstva-razvitiyu-za-2019
[20] https://www.mfa.gov.tm/
[21] Global sand and dust storms base map, consultancy reference number: CCD/18/ERPA/21
[22] Wiggs G.F., O'hara S.L., Wegerdt J., Van Der Meer J., Small I., Hubbard R. The dynamics and characteristics of aeolian dust in dryland Central Asia: Possible impacts on human exposure and respiratory health in the Aral Sea basin. Geogr. J. 2003; 169:142–157. doi: 10.1111/1475-4959.04976. [CrossRef] [Google Scholar]

Since the negative impact of air pollution on health is high even at relatively low PM concentrations, in order to minimize health risks to zero, an effective air quality assurance system must be created, the goal of which will be to achieve the levels recommended by WHO[23]. With the aim of improving the pulmonary service, the Ministry of Health and Medical Industry of Turkmenistan has developed and adopted a strategy on “Combating nonspecific lung diseases”. The goal of this strategy is to qualitatively improve primary, secondary and tertiary prevention, diagnosis and treatment of respiratory diseases, to significantly reduce the occurrence of pathologies in this area, and to stimulate research on the most common respiratory diseases.

2.3. Analysis of the legal framework for management and mitigation of the negative impact of SDS.

One of the first legislative acts of Turkmenistan related to the environment and natural resources, adopted after independence, was the Law on Nature Protection (1991), which became the basic document governing socio-economic and environmental legal norms. A new edition of this law was published in 2014.

The main legislative acts related to the management of SDS and climate change in Turkmenistan are:

- The Constitution of Turkmenistan of May 18, 1992 as amended on September 14, 2016[24].
- The Law of Turkmenistan “On Nature Protection” dated March 01, 2014 (Bulletin of the Mejlis of Turkmenistan, 2014, No. 1, Art. 40) (As amended by the Law of Turkmenistan dated August 18, 2015)
- The Law of Turkmenistan “On the Protection of Atmospheric Air” dated December 20, 1996 (Bulletin of the Mejlis of Turkmenistan 1996 No. 4, Art. 66) (With amendments and modifications introduced by the Law of Turkmenistan dated April 18, 2009 No. 32-IV)
- The Law of Turkmenistan “On sanatorium and resort activities” dated August 04, 2012 (Bulletin of the Mejlis of Turkmenistan, 2012, No. 3-4, art. 61) (Extract)
- The Law of Turkmenistan “On flora” dated August 04, 2012 (Bulletin of the Mejlis of Turkmenistan, 2012, No. 3-4, art. 60)
- The Law of Turkmenistan “On Animal World (Fauna)” dated March 02, 2013 (Bulletin of the Mejlis of Turkmenistan, 2013, No. 1, Art. 4)
- The Law of Turkmenistan “On Environmental Expertise” dated August 16, 2014 (Bulletin of the Mejlis of Turkmenistan, 2014, No. 3, Article 108).
- The Law of Turkmenistan “On Pastures” dated August 18, 2015.
- The Law of Turkmenistan “On Environmental Information” (March 14, 2020.)
- Sanitary Code of Turkmenistan (new edition) dated November 21, 2009. Bulletin of the Mejlis of Turkmenistan 2009, No. 4, article 77. (Extract)
- Forest Code of Turkmenistan Approved by the Law of Turkmenistan dated March 25, 2011. Bulletin of the Mejlis of Turkmenistan, 2011, No. 1, article 10. (With changes and ammendments introduced by the Law of Turkmenistan dated February 28, 2015)
- State Program “Health” (National Program “Saglyk”) (1995).

All these laws are aimed at reducing risks in the context of climate change and, to a certain extent, at addressing issues on the management of SDS in Turkmenistan. Turkmenistan was among the first to join the UN environmental conventions, which are the guarantor of the preservation of

[23] Health effects of particulate matter. Implications for Policy Development in Eastern Europe, the Caucasus and Central Asia https://www.euro.who.int/__data/assets/pdf_file/0006/189051/Health-effects-of-particulate-matter-final-Eng.pdf?ua=1https://www.euro.who.int/__data/assets/pdf_file/0006/189051/Health-effects-of-particulate-matter-final-Eng.pdf?ua=1

[24] Bulletin of the Mejlis of Turkmenistan, 2014, No. 1, art. 40 (With amendments and modifications, adopted by the Law of Turkmenistan dated 08/18/2015)

the environment and the prevention of environmental disasters on a global scale. These include: Framework Convention on Climate Change, Convention on Biological Diversity, Vienna Convention and Montreal Protocol for the Preservation of the Ozone Layer, Convention to Combat Desertification, Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, Aarhus Convention on Access to Information, public participation in decision-making and access to justice in environmental matters.

Table 2.

№	Name of convention	Year of adoption
1.	United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and / or Desertification, Particularly in Africa	The convention was signed in 1994. The Mejlis of Turkmenistan ratified this convention in June 1996.
2.	UN Framework convention on Cimate CHange	The convention was signed on May 9th, 1992. Turkmenistan signed this convention on May 1st, 1995. The objective of the Convention is to achieve, in compliance with the relevant provisions of the Convention, the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic impact on the climate system.
3.	Convention on Biodiversity	The convention was adopted in 1992. In Turkmenistan, it was ratified in 1996.
4.	Vienna Convention for the Protection of the Ozone Layer and Montreal Protocol on Substances that Deplete the Ozone Layer	Convention adopted in 1985.
5.	Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters (Aarhus Convention)	Adopted at the Fourth Ministerial Conference "Aarhus Environment for Europe" in Aarhus, Denmark on 25th June 1998. Turkmenistan was among the first to join the Aarhus Convention by ratifying it on April 30th, 1999.

However, a general analysis of the legal framework for management and mitigation of the negative impact of SDS clearly shows the need to develop special laws: "On sand and dust storms", "On soils", "On insurance against climate risks" and the organization of early warning systems. The development of regulations will allow in the future to reduce to a minimum their overall negative impact on the economy and health of the population of Turkmenistan. In addition, it is necessary to improve the regulatory framework of existing laws, in particular the Code of Turkmenistan "On Land" (2004) Article 5. - On the procedure for providing information to interested parties about the availability, condition, use and protection of land and other bylaws.

3. Implementation of the National Strategy for the Management of SDS Processes

3.1. The main beneficiaries: government organizations, scientific, regional and international and their roles in management of SDS processes

The list of stakeholders was formed based on the degree of influence on activities related to the solution of issues on the development of SDS. Priority ministries and departments include:

1. Mejlis;
2. Ministry of Agriculture and Environmental Protection and its subordinate structures;
3. Ministry of Finance and Economy;
4. Ministry of Health and Medical Industry;
5. State Committee for Water Resources;
6. State Committee on Statistics;

7. Union of Industrialists and Entrepreneurs;
8. Academy of Sciences of Turkmenistan

In addition, some of the following ministries and institutions may be included in the work process:

- Ministry of Education of Turkmenistan
- Ministry of Oil and Gas of Turkmenistan
- State Concern “Turkmenneft”
- State Concern “Turkmengaz”
- Ministry of Energy and Industry of Turkmenistan
- Ministry of Construction of Turkmenistan
- Institute of Oil and Gas of the State Concern “Turkmengaz”
- National Institute of Deserts, Flora and Fauna of the Ministry of Agriculture and Environmental Protection of Turkmenistan
- Institute for Strategic Planning and Economic Development of Turkmenistan
- Institute of Chemistry of the Academy of Sciences of Turkmenistan
- Institute of Transport and Telecommunications

President of Turkmenistan signed a Resolution at an expanded meeting of the Cabinet of Ministers of Turkmenistan, held on October 24, 2020, between our country and international structures in the field of environmental protection in various areas, organizing the fulfillment of the obligations assumed to implement the requirements of the relevant international agreements signed and approved by Turkmenistan, in accordance with which the Intersectoral Commission on the Environment was established.

In December 2015, a global document was adopted - Paris Agreement on Climate - which Turkmenistan ratified on October 21st, 2016. The global community has outlined a new Climate Agenda in the context of the adoption of the Sustainable Development Goals (SDGs). With the adoption of commitments under the Paris Agreement and the implementation of the SDGs, a new National Strategy of Turkmenistan on Climate Change was prepared in 2019 with the participation of specialists from the Ministry of Agriculture and Environmental Protection with the support of the United Nations Development Program (UNDP) and the German Society for International Cooperation (GIZ) ...

The new edition of the National Strategy of Turkmenistan on Climate Change also meets the objectives of the Program of Socio-Economic Development of Turkmenistan for the period 2019-2024. Studies have shown that the economy of Turkmenistan has a high potential to reduce the negative impact of the SDS processes on the economy and health of the country's population.

3.2. Action Plan for Building Capacities for Effective Management of Sand and Dust Storms in Turkmenistan

The aim of developing an Action Plan (AP) is to improve systemic and institutional capacity to implement effective and sustainable sand and dust storm management (SDS) in Central Asian countries. It will improve coordination and cooperation between organizations and communities to reduce their negative impact, and will also serve as a basis for joint work at the subregional level. Specific objectives of the AP are as follows:

- Expansion of the application and implementation of modern technologies and techniques to combat the processes of SDS;
- Strengthening strategic and institutional foundations of management and strengthening individual capacity of the country in combating these processes;

- Improving interaction between government agencies and departments, research institutes, universities, NGOs through the development of human resources;
- Expanding influence on the mechanisms of political decision-making and legislative acts in the field of sustainable management of the SDS processes;
- Strengthening cooperation between CA countries and international cooperation for the exchange of successful methods, approaches and modern technologies, as well as identification of needs for targeted education and training.

The AP was developed as a long-term strategy to enhance the implementation of the NAPCD tasks in the field of counteracting the intensification of the SDS processes and increasing their negative impact on the country's economy against the general background of the development of desertification and drought processes.

In particular, various state bodies (Ministry of Agriculture and Environmental Protection of Turkmenistan, State Committee for Water Resources of Turkmenistan, Ministry of Oil and Gas of Turkmenistan, State Concern “Turkmenneft”, State Concern “Turkmengaz” and other departments) separately carry out separate measures to combat SDS processes within the framework of their authority and capabilities. The AP offers a basic framework for pooling efforts and opportunities, both at the national and regional levels of its use.

In addition, it allows you to develop a common platform for the introduction of new curricula, as well as the development of practical courses in Central Asia to improve the qualifications of specialists and train personnel on the problems of SDS. In the future, it will be possible to consistently implement an active exchange of experience and best methods and technologies to combat the processes of BSP, both in a single country and in all CA countries.

Effective implementation and achievement of the objectives of the proposed strategy is possible with the adoption of regulatory documents for management of SDS processes and reducing their negative impact on the environment, economy and health of the population of the country. In view of the above, we propose the adoption of laws: “On SDS”, “On soils”, “On insurance against climate risks”. They are aimed at: Improving soil fertility, protecting land from anthropogenic and natural degradation processes; Management and mitigation of the negative impact of sand and dust storms in Turkmenistan; Agricultural producers and entrepreneurs can receive compensation in the event of natural disasters, including from the SDS.

Below is the developed Action Plan for building capacity for effective management of sand and dust storms in Turkmenistan (Table 3) and the Action Plan (Table 4).

Action Plan for Building Capacities for Effective Management of Sand and Dust Storms in Turkmenistan

Table 3.

№	Activity	Implementing agency	Counterparts	Timeframe	Source of financing	Expected result
1	2	3	4	5	6	7
System level						
1.	Development of the Law "On Soils"	MA&EP, Mejlis	MoE, SCWM, AS of Turkmenistan,	2025	Budget	Improving soil fertility, protecting land from anthropogenic and natural degradation processes
2.	Develop a by-law to the Code of Turkmenistan "On Land" - Article 5. The procedure for providing information to interested parties on the availability, condition, use and protection of land;	MA&EP, Mejlis Ministry of Finance and Economy Ministry of Justice, SCS	MA&EP	2027	Budget, donor funds	Provide awareness of various departments for joint action
3	Develop by-law to the Code of Turkmenistan "On Land" - Article 103: procedure for economic incentives, rational use and protection of land	MA&EP, Mejlis Ministry of Finance and Economy Ministry of Justice, SCS	MA&EP, SCWM	2027	Budget, donor funds	Interest of land users and tenants in land in use

4	Development of the Law "On SDS"	MA&EP, Mejlis	MOE, MoHMI, SCWM	2025	Budget	Management and mitigation of the negative impact of sand and dust storms in Turkmenistan
5.	Development of the Law "On Insurance against Climate Risks"	MA&EP, Mejlis	SCWM, NIDFF, AS of Turkmenistan, Union of Industrialists and Entrepreneurs	2026	Budget	Agricultural producers and entrepreneurs will be able to receive compensation in the event of natural disasters, incl. from SDS
			Institutional level			
1.	Development of a program for interagency coordination in the field of SDS	MA&EP, SCWM	MA&EP	2027-2028	Budget	Improving the effectiveness of interagency cooperation in land administration
2.	Creation of a national network of experts on land and water resources in the field of SDS	MA&EP, SCWM	MA&EP	2027-2028	Budget, donor funds	Improving the efficiency of cooperation of all stakeholders
3.	Creation of a center for land monitoring using geographic information systems in the field of SDS	MA&EP	Ministry of Finance and Economy, SCWM	2028-2029	Budget, donor funds	Assessment and forecast of the state of lands in order to create conditions for the rational use of lands, reproduction of their fertility, as well as preservation of the natural environment

4.	Create a national information center for forecasting and management of SDS processes	MA&EP	AS of Turkmenistan, NIDFF, hydrometheorology service	2028-2029гг	Budget, donor funds	Improving information forecasting and analysis of SDS processes

Action Plan for Sand and Dust Storm Control in Turkmenistan **Table 4.**

№	Name of activity	Timeframe	Sources of cinancing	Implementing agency
1.	Develop a national program to combat soil salinization in northern Turkmenistan due to salt transfer from the drained bottom of the Aral Sea.	2025	Budget, IFAS, donor funds	MA&EP, SCWM, line ministries.
2.	Carrying out large-scale forest reclamation activities in the Dashoguz velayat near the Botendag Upland and other regions in order to prevent the transfer of dust and salts to the country from the Aral Sea.	2021-2030	Budget, donor funds	MA&EP, UIET, line ministries and local authorities
3.	Training of national personnel in SDS process management in universities of the country and in foreign countries.	2025-2030	Budget	ME
4.	Release of atlas of Turkmenistan with GIS maps on environmental protection and combating desertification processes.	2025-2030	Budget, donor funds	MA&EP, MF and E, MOE, SCWM
5.	Best practices for dealing with SDS processes adapted and widely adopted by stakeholders.	2021-2030	Budget, donor funds	MA&EP, MF and E, MOE, SCWM

6.	Implementation of computer programs and organization of training courses on the use of GIS - technologies in the field of SDS.	2021-2030	Budget, donor funds	MA&EP, MF and E, MOE, AS, SCWM
7.	Expansion of modern internship centers to strengthen and improve SDS professionals.	2021-2030	Budget, donor funds	MA&EP, MF and E, MOE, AS
8.	Implementation of a system for prevention of diseases from negative impact of dust on the human body	2021-2030	Budget	MoHMI
9.	Regular inventory of pastures and water sources	2021-2030	Budget, donor funds	MA&EP, MF and E, AS, SCWM
10.	Improving the efficiency of monitoring desertification processes	2021-2030	Budget, donor funds	MA&EP, MF and E, AS, SCWM
11.	The use of modern crop rotation schemes and progressive irrigation methods, soil cultivation technologies	2021-2030	Budget, donor funds	MA&EP, SCWM, local authorities
12.	Regular monitoring of soil salinity in irrigated lands with salt survey (every 3-5 years)	2021-2030	Budget, donor funds	MA&EP, SCWM
13.	Development of collector and drainage network and reconstruction of irrigation systems	2021-2030	Budget, donor funds	MA&EP, MF and E, SCWM
14.	Teaching courses on forest reclamation and advanced training of forestry specialists in agribusiness schools	2021-2030	Budget, donor funds	MA&EP, MF and E, ME
15.	Expansion of publishing activity on the problems of rational and respectful attitude to the land	2021-2030	Budget, donor funds	Media, MF and E, AH

3.3. Conducting ground monitoring and assessing the scope of SDS processes

Due to the spatial incompatibility of the data on the intensity of SDS sources on the global basemap of SDS sources (the initial data of soil moisture and soil temperature have an initial resolution of 0.25°), in some areas, the visual impact of the coarse resolution data at the boundaries is possible, where on one side the threshold exceeded, but on the other not. This is a common problem with numerical evictions and requires improvement in the quality and resolution of the raw data due to the complexity of the ground conditions. To plan actions in the field, you need to have additional field observations.

Real wind data were not taken into account for SDS source mapping because the baseline SDS source map represents the ability of the soil surface to form SDS. The wind strongly and quickly changes directions in time and space, therefore some high-resolution data in the form of a stable indicator is completely absent. Winds that generate intense, local SDS sources can also flow for a short time and therefore are not observed in observations, especially on climate datasets. The same problem applies to SDS observations, which are based on satellite and separate ground-based measurements. Dust climate simulations performed in conjunction with atmospheric dust models that can combine high-resolution SDS source information, including local hotspots and can produce strong local winds such as the hubub, will require a high spatial resolution of several kilometers, which is beyond computational capabilities. available for climate simulations globally.

Studies that take into account the activation of SDS should include data of regional, national and local nature, and be performed with a vulnerability and risk assessment using national data and/or the use of combined high-resolution atmospheric and dust simulation models. Also, additional field observations of soil surface conditions, wind and SDS are desirable. Traditional ground-based observation methods include observation towers, video surveillance, and sensor information. Ground-based observations are more accurate and detailed. However, they cannot isolate dust transport on a large scale.

Wireless sensor networks are becoming very common for accurate, timely and continuous observations of a dust-producing region today. Data required for a wireless sensor network-based SDS allocation system include:

- Atmospheric pressure: measurement of pressure at any point affected by the earth's atmosphere. It plays an important role in the creation of storms, cloud formation and wind movements, moving air from areas of high pressure (low temperature) to areas of low pressure (high temperature).
- Surface temperature: measurement of the air temperature two meters above the surface. It shows how dry and hot a surface is and affects the amount of dust blown up by the wind.
- Moisture: the amount of moisture in the air two meters above the surface. Moisture can be picked up by the movement of the dust, creating aerosol dust that can be carried by the wind for miles.
- Wind speed: the speed and direction of movement of air from a high pressure area to a low pressure area. Strong winds can lift dust off the surface and carry it to remote areas.
- Soil moisture: measurement of the water content in the topsoil. It affects vegetation growth, soil erosion, etc.

Additionally, wireless sensor networks provide useful information including light and visibility, time and location. It is important to note that high wind speed is a necessary, but not sufficient condition for the formation of dust storms.

3.4. Sources of funding for the implementation of the National SDS Strategy

Both domestic and international funding sources will be used to implement the National SDS Strategy.

Domestic resources include:

- state funds, which in turn consist of budgetary sources of financing, funds of the foreign exchange reserve fund of Turkmenistan, own funds of enterprises and organizations;
- borrowed funds, which include loans from domestic banks and budget funds allocated on returnable basis;
- funds of farmers' associations;
- funds of private business and non-governmental organizations;
- funds of the population.

Funds raised from outside the country have traditionally made a certain contribution to most projects in the field of environmental protection and its components. Despite this, these sources of funding are additional resources to domestic funding sources. Potential categories of external funding sources include:

- Bilateral donors;
- Multilateral donors;
- Private sources such as foreign direct investment, commercial or corporate social responsibility projects, commercial loans, etc .;
- Expatriate funds;
- International NGOs;
- International charities.

In 1995, independent Turkmenistan joined the UN Convention to Combat Desertification, and in 1996 the country's Parliament ratified it. The same year, the Government Commission was established to develop a concept and strategy for combating desertification. Since joining the convention, the country has mainly implemented projects with the participation of bilateral and multilateral donors. Turkmenistan closely cooperates with UNDP, GEF, FAO, German Society for International Cooperation (GIZ), the Secretariat and the Global Mechanism of the UN Convention to Combat Desertification, CAREC and other international organizations on issues of combating desertification. In addition, the South Korean International Cooperation Agency KOICA provides technical assistance to the Land Resources Service of the Ministry of Agriculture of Turkmenistan in the development of GIS technologies. Cooperation of Turkmenistan with international organizations such as GEF, UNEP, ESCAP, USAID, World Bank (WB) and others is developing. The international donor community has made a significant contribution to combating desertification processes in Turkmenistan, which includes SDS processes. Turkmenistan took an active part in the implementation of three multi-country projects and country projects in the field of combating desertification and the field of SLM. Asian Development Bank (ADB), German Agency for International Cooperation (GIZ), Global Environment Facility (GEF) and the United Nations Development Program (UNDP) took part in financing of these projects.

Conclusion

Sand and dust storms are a common meteorological phenomenon in arid and semi-arid regions of the world, including Turkmenistan. Sandstorms travel relatively close to the ground, while dust storms can lift miles into the atmosphere and travel long distances. Strong winds lift large amounts of sand and dust from exposed dry soils into the atmosphere, carrying them hundreds and thousands of kilometers. About 40% of solid or liquid particles suspended in the air

- aerosols, in the troposphere (the lowest layer of the earth's atmosphere) are dust particles from wind erosion. According to global estimates, dust emissions range from 1 to 3 gigatons per year (equal to 10^9 (billion) tons or 10^{12} (trillion) kg). Dust storms can travel thousands of kilometers over continents and oceans, capturing other pollutants along the way and depositing particles far from where they originated.

Central Asia is distinguished by the most disturbed desert surface with overgrazing of livestock and secondary salinization, developed on irrigated lands, depletion of water resources, etc. The toxicity of desert dust clouds can be influenced by anthropogenic material through aerosolization of pollutant particles during cloud formation or cloud capture during downwind transport (adsorption of pesticides, herbicides and industrial emissions, etc.). Intrinsic toxicity is due to differences in the natural elemental composition of the soil (metals and natural or synthetic radioisotopes, etc.), chemical changes in the atmosphere, size fractionation and extreme loading of particles. Toxic metals such as arsenic and mercury are found in airborne desert dust in the downwind environment at concentrations in excess of regional crustal concentrations. In addition to the presence of these toxic metals, dust can indirectly affect human health by causing toxic algal blooms in coastal environments (i.e. red tides in which marine organisms use dust components such as iron as a nutrient in nutrient-depleted waters).

The tragedy of the Aral Sea is one of the largest global environmental disasters in the modern history. Today, it affects the 62 million population of Central Asia, threatening the sustainable development of the region, health, gene pool and the future of the people living in it. Direct consequence of the drying up of the sea is in dramatic climate change, felt not only in Central Asia, but also in other regions. The Aral Sea crisis zone directly covers the territories of Turkmenistan, Kazakhstan and Uzbekistan, as well as indirectly - Tajikistan and Kyrgyzstan. A new salt desert with an area of 5.5 million hectares has appeared on the dried part of the bottom of the Aral Sea. Over 90 days a year, dust storms rage over it, carrying over 100 million tons of dust and toxic salts into the atmosphere for many thousands of kilometers annually. According to international experts, poisonous salts from the Aral region have been found on the coast of Antarctica, on the glaciers of Greenland, in the forests of Norway and many other parts of the world. The most important task of the present time is to reduce the destructive impact of the Aral Sea crisis on the environment and the livelihoods of millions of people living in the Aral Sea region. Dust storms carry toxic dust over long distances, affecting the surrounding ecosystems and causing not only respiratory problems, but also cancer of the larynx and esophagus.

Solving the problems of negative propagation of SDS processes requires activities towards the following challenges:

- Neutralize the development processes of SDS, which should contribute to the sustainable development of the sectors of the economy of Turkmenistan, primarily agriculture, desert animal husbandry and the efficient operation of various engineering facilities located in desert conditions;
- Direct efforts to significantly reduce the formation and concentration of dust in the air, which will protect the health of the country's population;
- The solution to the problems of combating intensive development of SDS processes will be carried out on the basis of the integrated use of modern technologies and methods of protecting various engineering facilities and settlements from the transfer of sand and dust;
- Expansion of reforestation territories and carrying out phytomeliorative measures on various types of ecosystems of Turkmenistan;
- Improvement of the country's regulatory framework for the adoption of laws to combat SDS processes, creation of an early warning system and development of these processes;

- Strengthening regional cooperation among Central Asian countries in combating the development of SDS processes;
- Scaling up research work to develop innovative technologies to neutralize SDS challenges;
- Creation of a national monitoring system for the state of the foci of dust storm formation and sand transfer;
- Training of personnel to combat SDS processes in higher educational institutions of Turkmenistan.

Implementation of the National Strategy of Turkmenistan for Management of Sand and Dust Storms will significantly reduce their negative impact on the economy and health of the country's population.

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Anex 1.

Forest growing conditions in the regions of potential SDS development

Table 5.

№	Types of forest growing conditions	Description of the relief	Soil	The nature of the phytomelioration work	Views on recommended vegetation
1.	There are five main types of forest growing conditions in the Central and Zaunguz Karakum Desert. Type I. In general, this type is favorable for carrying out phyto-reclamation works.	Within this group, depending on the thickness of the eolian sediment and the dissection of the relief, as well as the nature of the soil and vegetation cover, salinity and water-physical properties, there are cumulus,	Sandy desert soils on aeolian sands lying on the Middle and Upper Quaternary alluvial-deltaic sediments of the Dekchinskaya (younger) and Shakhmuradovskaya (ancient) deltas of the Amu Darya.	In general, this type is comparatively favorable for carrying out phyto-reclamation works. The worst forest growing conditions have dune sands, which are distributed mainly in the south of the Garaporsang massif in a complex with hilly dune sands.	In saline areas, it is better to plant various types of halophytes: potash, sarsazan, saltpeter, kazgan and other species. On separate scattered sandy massifs, located among the developed lands, as well as in the zone of contact of the desert with oasis landscapes, we recommend sowing and planting

		hilly, hilly-dune sands.			of black saxaul, cherkez, kandim.
2.	Type II. Two subtypes are distinguished. Subtype II a. Subtype II b.	Fine and coarse sands and flat ridges of the Zaunguz Karakum. The sandy relief of this subtype is of Late Pliocene Quaternary age. The height of the molds is 5-8 m, and in some places 10 m. Large and small aeolian forms on the kyrs and in the kyr valleys (350-250 km). This territory is characterized by ridge-remnant and kyr relief (height 30-60 m).	Sandy desert soils as well as gray brown soils. Sandy desert soils on fine and large ridge-basin sands. There are also takyrs among the sands. Gray brown and sandy desert soils are widespread here.	Dunes with a height of 2-5 m are widespread in the transitional zone of the oasis sands, which pose a threat to linear engineering objects. In general, unfavorable conditions for carrying out phytomelioration works due to the high dissection of the relief.	If areas where a sandy relief is partially fixed by herbaceous vegetation, they only need to carry out measures for the natural overgrowing of psammophytes with shrubs. In the rest of the desert ecosystems, it is mainly cherkez, kandym, white and black saxauls that are recommended. Everywhere on thin sands, sandy takyrs and the lower part of slopes and hillocks on the entire surface of small ridges, bridges, hillocks, cumulus sands, black saxaul, Richter's Cherkez and Kandym, small-fruited and densely bristle, are acceptable for planting.
3.	Type III. There are two subtypes: Subtype III a. Subtype III b.	The sandy relief here is very diverse and there are small-barkhan forms, hilly, small medium-barkhan and bumpy-dune hollow sands. Large-bed, large-bed-hollow, cellular-ridge sands. This subtype in the Erbent region is represented by a	Typical sandy desert primitive soils lying on alluvial lower - middle Quaternary deposits of the Karakum Formation.	The considered type of forest growing conditions is also unfavorable and covers typical desert areas between Bakhardok and Darvaza. The Priunguz zone is a zone where the deposits of the Karakum and Zaunguz formations meet. They are comparatively favorable for phytomelioration with the obligatory installation of mechanical protections.	According to the established mechanical protections, planting and sowing of sand-strengthening plants. Saplings of saxaul, kandym, cherkez should be planted at the full rate of 3.5 thousand pieces / ha. The sowing of the seeds of these plants is also carried out at the full rate: Kandym and Cherkez are sown at 6-9 kg / ha, and saxaul 6-8 kg / ha.

		significant massif of dune sands. According to the Institute of Deserts, arrays of dunes are widespread: near the village of Bokurdak on an area of about 150 hectares, in the Erbent region - 430 hectares, near Karadzhulba - 180 hectares.			On sand dunes - installation of mechanical protections with black saxaul, kandym, cherkez planting. In places of intersection of large, high and medium ridges, lying on takyrs and takyr-like deposits on the upper obarchite part, it is advisable to use tree-like kandym, white saxaul, Paletsky cherkez for planting. On aeolian sands lying on loose sandy deposits of the pre-Amu Darya, it is necessary to use white saxaul everywhere. In inter-ridge depressions, or thin sands near takyrs, on thin, small, medium bridges, it is advisable to plant kandym and cherkez.
4.	Type IV.	Coarse sands lying on the alluvial-deltaic sediments of the ancient delta of the Tejen River with deep mineralized groundwater.	Sandy desert soils, large areas of takyrs and takyr-like soils.	In general, this type is comparatively favorable for carrying out phyto-reclamation works.	Here, on the upper third of the slope of the middle ridges, the middle and upper parts of the slope of large ridges, only white saxaul should be planted, given the thickness of the sandy deposits. Planting psammophyte shrubs should be carried out selectively on the slopes of ridges, strongly dissected by blowing ulcers at a distance of 60 to 150-200 m.
5.	Type V.	This type is characterized by	Sandy desert soils lying on alluvial and	The northern boundary of this type of forest growing	On the border of fallows and salt marshes, planting of cuttings of

		significant slope of the surface, local variegation of the relief. The type is combined with a ridge-hilly relief, and in the north - with takyrs and ridge sands lying on the ancient Tejen delta.	proluvial deposits with different salinity and depth of groundwater. Among the sands there are depressions with takyrs, takyr-like soils.	conditions is the area of contact of the foothill plain with the sediments of the ancient Tejen delta, where the latter are overlain by proluvial sediments. The conditions for carrying out phyto-reclamation works are generally favorable.	sucker, comb, turanga, and black saxaul seedlings. In places where sandy deposits are spread: a) in the presence of seed-bearing shrubs, facilitating the natural renewal of trees and shrubs by strictly guarding 1000-1500 m of the strip on each side. With moving sands, install mechanical protection with sowing a full norm of seeds of kandim, cherkez and black saxaul. On single medium and large hillocks and other forms - planting of kandym, cherkez and saxaul.
6.	Western Turkmenistan	Modern aeolian sands prevail, lying on loose sandy Novo-Caspian deposits. This is a strip of small-pebbled chains. The surface of the dune chains is covered with multi-colored pebbles, giving the sand a whitish color.	Fine-grained sands: fraction 0.25-0.05 mm - 82.0-94.7%, physical clay - 1.9-6.1%. Bulk density - 1.44, specific - 2.63 g / cm3, porosity - 45.2%, hydroscopicity - 0.5, available moisture in July (in 0-150 cm layer of sand) - 13.7, total stock moisture - 33.1 mm. The moisture content of the sands in the summer months in the 0-150-cm layer averages 0.6-0.9%.	In general, this type is extremely unfavorable for carrying out phyto-reclamation works due to the high salinity of soils. In the Jebel region, the sands are more favorable for fixing them with vegetation.	In the Jebel area, we recommend planting and sowing white and black saxaul (Haloxylon persikum), (Haloxylon aphyllum), woolly kandym (Calligonum eriopodum), reddish kandym, C. rubens, (Calligonum arborescens) and jellyfish head kandym (C. kaput-medusde). On thicker sandy deposits of the relief, white saxaul, woolly kandym and jellyfish head, as well as tree kandym (Calligonum arborescens) and Richter's cherkez (Salsola richteri) are advisable. On saline depressions, it is advisable to plant a heath

			Sands are slightly saline: dry residue - 0.34, chlorine - 0.04%, humus content in the upper horizons (0-50 cm) - 0.55-0.80, and in the lower (50-150 cm) - 0.26 -0.41%. The groundwater is located at a depth of 0.7-1.5 m and is highly mineralized (300 g / l). Salinity type is sulfate-chloride. Humus content is 0.18-0.60%.		(Tamarix sp.), Turanga or poplar (Papulus pruinosa), atriplex (Atriplex sp.), Saltpeter.
7.	Eastern Turkmenistan. Three types are distinguished: Type 1.	Dune fields - systems of equal altitude relief, and dune chains 5m high on a flat plain moving at the same speeds.	Sandy desert soils formed on overwhelmed aeolian sands. The depth of groundwater is up to 10 m. On the northeastern edge of the sands, i.e. In the 15-meter strip of contact with the middle Amudarya oasis, groundwater occurs at a depth of 3-5 meters and is slightly mineralized (up to 5 g / l). It should be noted that	Within the limits of type I forest growth conditions, the greatest danger is created by the dune massifs of aeolian sands.	The peculiarity of the soil-climatic, forest-growing and aerodynamic conditions of the territory necessitates the selection of the appropriate tree and shrub species. Their assortment is recommended by us with possible changes in the depth and salinity of groundwater. Planting and sowing of black saxaul, white saxaul, tree-like kandym, jellyfish head kandym, small-fruited kandym, Paletsky cherkez is advisable on the bare massifs of sands.

	Type 2.	Outliers, Late Khvalyn takyrs and sandy ridges with a height of 3-5 m are widespread on this surface. Aeolian ridges are fixed here with vegetation.	in the Area of the Repetek Nature Reserve, at a depth of 6-8 meters, there is a lens of fresh (0.5 g / l) water; around it, in a strip up to 6 km wide, there is a transitional strip with a mineralization of 5-6 g / l.	In general, this type has favorable conditions for carrying out phyto-reclamation works.	On sandy forms and thick sandy deposits, it is advisable to sow white saxaul, woolly-legged kandym, jellyfish head, treelike kandym, Richter's cherkez, Paletsky's cherkez. On sands of varying thickness, sandy clay surfaces and the lower part of the slope of high ridges, the lower and middle part of the slope of middle ridges, on the entire surface of small ridges, black saxaul, cherkez, kandym small-fruited, kandym jellyfish are acceptable.
	Type 3.	The northern part of the unit is represented by a continuous massif of sands in places with the presence of dunes, ridges and hillocks, and in places covered with sod, gently undulating sands. The southern part is presented in the form of scattered local massifs of weakly dissected overgrown sands of various thicknesses.	Sandy desert soils on aeolian sands lying on the denudation plain of Neogene sediments, with a groundwater depth of more than 20 m. The type is widespread in the Uchadzhi and Plain regions in the eastern part of the Mary section of the road. Ground soil has a mineralization of 8-12 g / l, suitable for a number of shrubs and black saxaul, but not available for other plant species.	In general, this type has very good favorable conditions for carrying out phyto-reclamation works.	On the upper third of the slope of the middle ridges, the middle and upper part of the slope of large ridges, white saxaul, Kandym treelike, black saxaul and Cherkez Richter should be planted. On sands and other soils with similar non-flowing saline ground waters to varying degrees (depth 0-1.5 m), the following are acceptable: comb, poplar variegated or turanga, atriplex. On sandy loam sands with close (depth 1.5-2 m) fresh flowing groundwater (on the outskirts of irrigated lands), it is advisable to plant: white mulberry, apple tree, quince, grapes, Eldar pine, thuja,

		In the northern part of the type, there are ridge-hilly sands. Their height is 20-25 m.	Sandy desert soils on sands lying on deltaic sediments of the late Quaternary and modern plain of the Murgab River with a depth of groundwater of 5-30 meters.		maclura. However, these plantations should be regularly watered for the first 2-3 years, and in places where the depth of groundwater is more than 3 meters - throughout the life of trees and shrubs. In areas with a close occurrence of groundwater adjacent to saline soils, saline depressions (depises), on saline soils with excessive moisture, we recommend planting atriplex, turanga, comb, eastern goose.

Anex 2.

Technologies and methods for protecting engineering facilities from sand and dust transfer

Sand drifts with dust removal of material on linear objects (roads, railways and pipelines) can be conditionally subdivided into linear, solid and their combinations. In addition, during the construction period, there is an intensive inflation of the embankment and canvas, especially on the massifs of dune sands (7,8,9,10). As protective materials, we propose to use various types of mechanical protection in combination with sowing and planting sand-strengthening plants (14). However, it should be noted that such protections are considered temporary (2-3 years), so they are strictly recommended only in combination with phytomelioration. For these purposes, cellular and multi-row semi-hidden mechanical protections are usually used, conditional to fixing their slopes to the tops. The width of the fixed zone on the dune sands varies within 10-500 m from the windward side and half that from the leeward side. Add additional clay into the intercellular space (layer thickness 2-3 cm). The size of the cages, depending on the wind regime, should be 2x2 m. The distance between ordinary defenses (from reeds) is selected depending on the wind speed and the steepness of the dune slopes. For example, when the wind speed does not exceed 17-20 m/s, and the steepness of the relief slopes is within - 5, 10, 15 degrees, on the windward slopes it is necessary to install protections at a distance of - 4, 3 and 2 m. When the wind speed exceeds 20 m/s, then the distance should already be - 3 and 2 m. In November or at the end of January, it is necessary to plant sand-strengthening plants, since by this time the dunes acquire a stable profile, and moisture accumulates in the sand sufficient for germination.

The technology of mechanical protection devices is as follows: along a pre-marked line, they dig a ditch 40 cm deep, above the sand surface, the height of the row should be 35 cm. The rows of protections are oriented perpendicular to the wind, the number of rows on the windward side is 10-14, and the leeward side is 6-8 rows (fig. 8). The essence of fixing technogenic sands is to stabilize the moving surface, to enable local vegetation to take root on it (10, 11, 12, 13). For these purposes, various designs of mechanical protection made from shrubs and grasses are used, installed in rows, cages in the form of fences or bedding. According to these protections, after the stabilization of the sandy surface (establishment of the equilibrium profile), seeds are sown or seedlings, as well as plant cuttings, are planted in a timely manner and according to certain norms. The best survival rate was found when using cuttings and seedlings of kandym (60-80%), rather high - in Cherkez seedlings (50-55%), and the lowest - white saxaul (30-35%). Experiments have shown that in areas where removal and accumulation are minimized, 90% of the planted plants are preserved, and in non-fixed areas, the death of plants is almost 100%. Local clay from takyrs is most convenient for securing (filling) the blown sand surface with a layer of clay up to 5 cm. This method contributes to the implementation of non-accumulation transfer of sand. Along the edges of the "armor" it is desirable to arrange a "lock" by pouring a fixing compound, which protects the edges of the "armor" from destruction (Fig. 9). We suggest the following use of takyr clay for fixing the flowing sand surface:

- Securing inflated (including planned) sandy surfaces. The essence of the fixing method is to sketch dry takyr clay with a layer of 2-3 cm, followed by spraying it with water in an amount of 2.5-3.0 l/m2. Clay consumption for continuous coverage is 200-300 m3 per hectare. If the surface to be fixed has the form of a strip (along the road) 50 meters wide, then at the same clay consumption, 100 meters can be fixed, i.e. one picket (on both sides of the road).
- Anchoring the dunes. Their consolidation consists in blocking the dune forms by installing rows of reeds on the frontal slope of the dune with a distance of 1 meter between the rows. In the absence of reeds, you can use dry takyr clay in the form of strips, poured into trenches 10 cm deep. The distance between the strips is 1 meter. Water consumption is 3 l/m2 of

the area to be fixed. This measure allows you to stop the movement of sand dunes, this method is called blocking mobile sand dunes. In the future, phyto-reclamation works can be carried out using such stable forms.

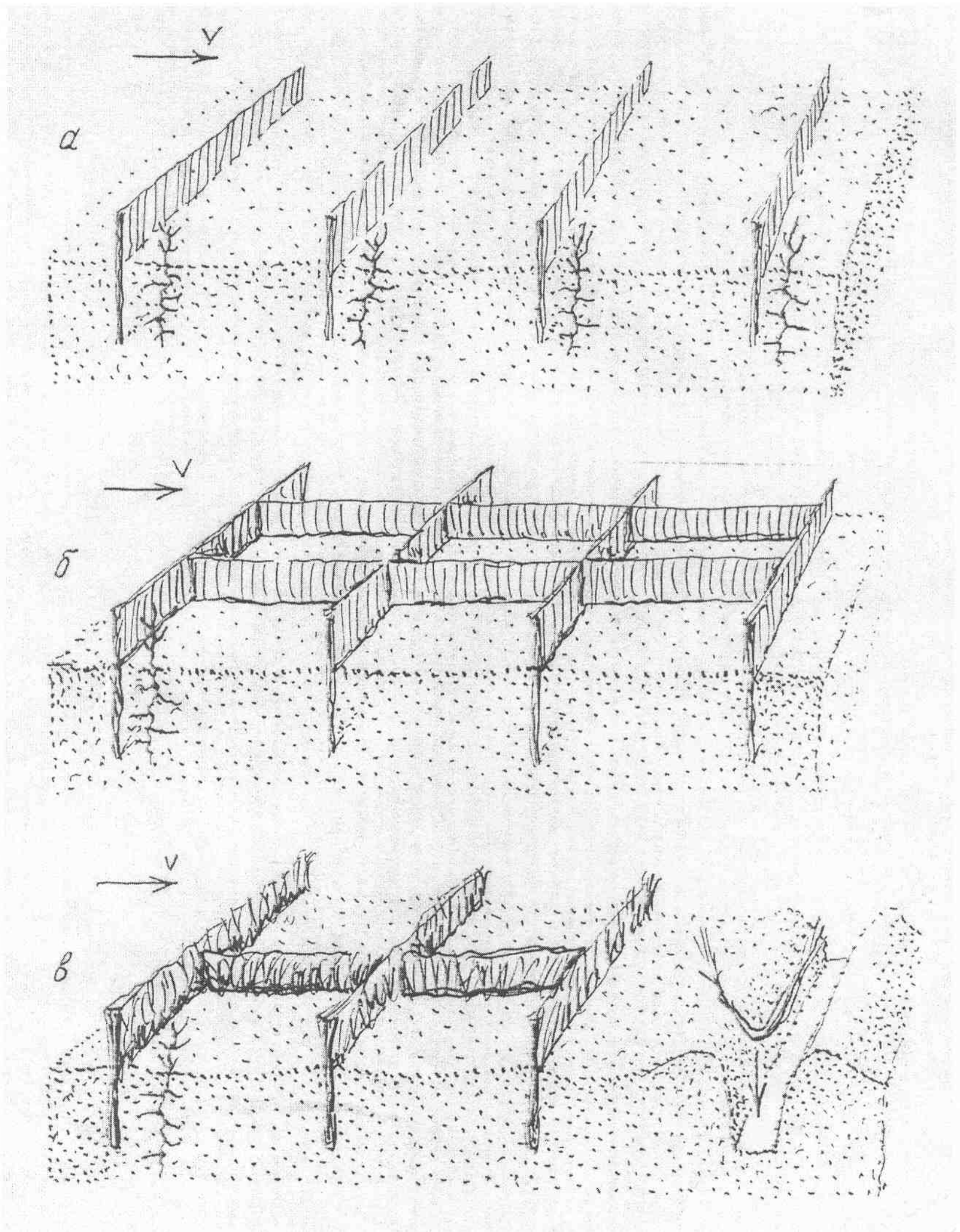

Fig. 8. Diagram of the arrangement of rows (a) and cells (b) from reed mats or from unbound reeds, the bundles of which are bent in half and inserted into the groove, as shown in the figure (c) with an arrow.

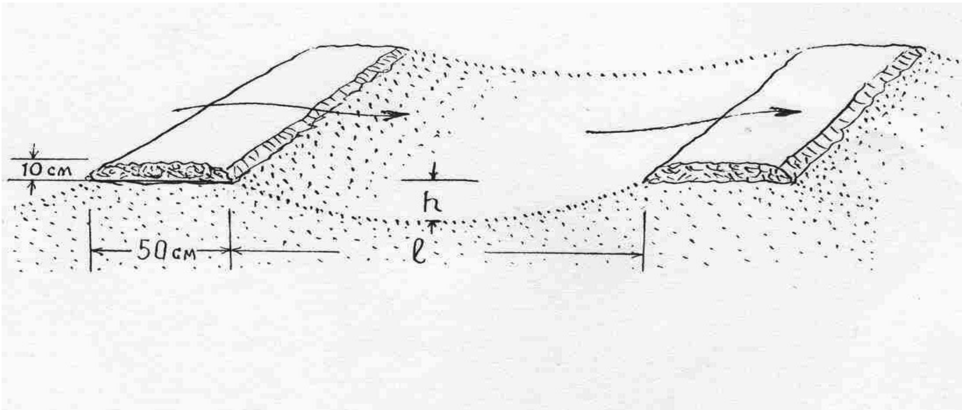

Fig. 9. Making strips from takyr clay.

We recommend installing semi-hidden mechanical protections from the tops of the molds onwards, i.e. rows of reeds, which are set in parallel rows at a distance of 2 m (Fig. 10). On the lower right side of the dunes, 5 rows are set, 35 cm high, 40 cm are buried in the sand. On the left, high dune strip of relief, 8 rows should be set perpendicular to the wind. In late autumn, it is necessary to plant plants in the intercellular space (3500 plants per hectare). At the end of November, you should sow kandym or cherkez, i.e. local vegetation.

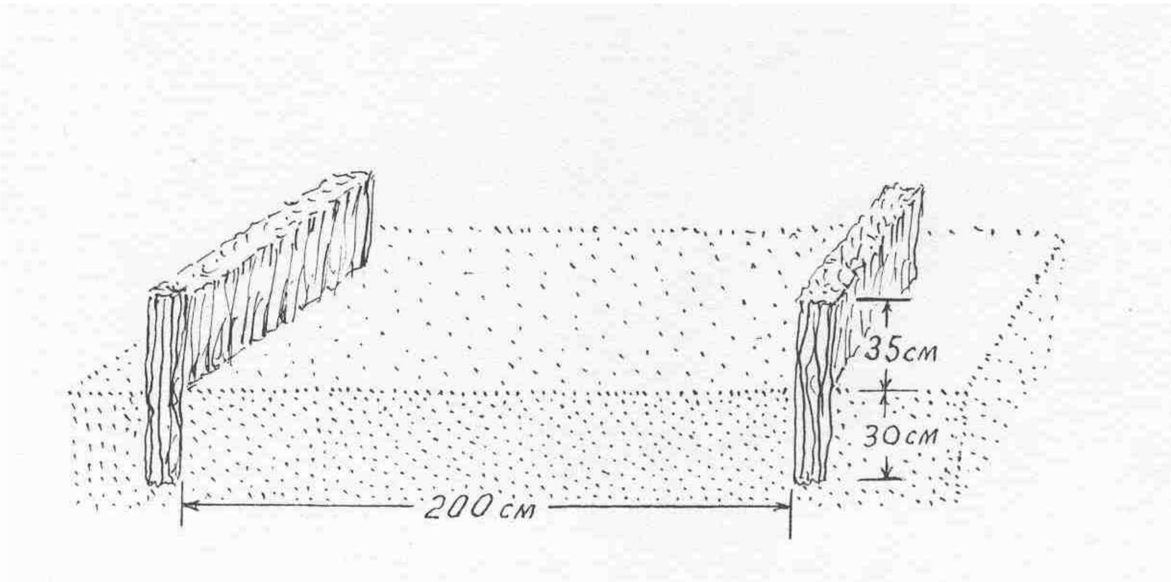

Fig. 10. Installation of ordinary cage protections from reeds.

The main forms of aeolian relief in Western Turkmenistan do not have a dynamic balance, and the high soil salinity and close occurrence of groundwater impedes the development of vegetation cover. In this regard, we recommend methods based on the principle of non-accumulative transfer of sand through protected objects. Its application assumes that the sand arriving at the structures should be passed without deposition on the objects themselves. A method of non-accumulative transfer of sand through a linear object without deposition. To solve the problem, it is necessary to give a scientific substantiation of the method, based on the developed impulse theory of separation and movement of sand particles in a wind-sand flow (Fig. 11).

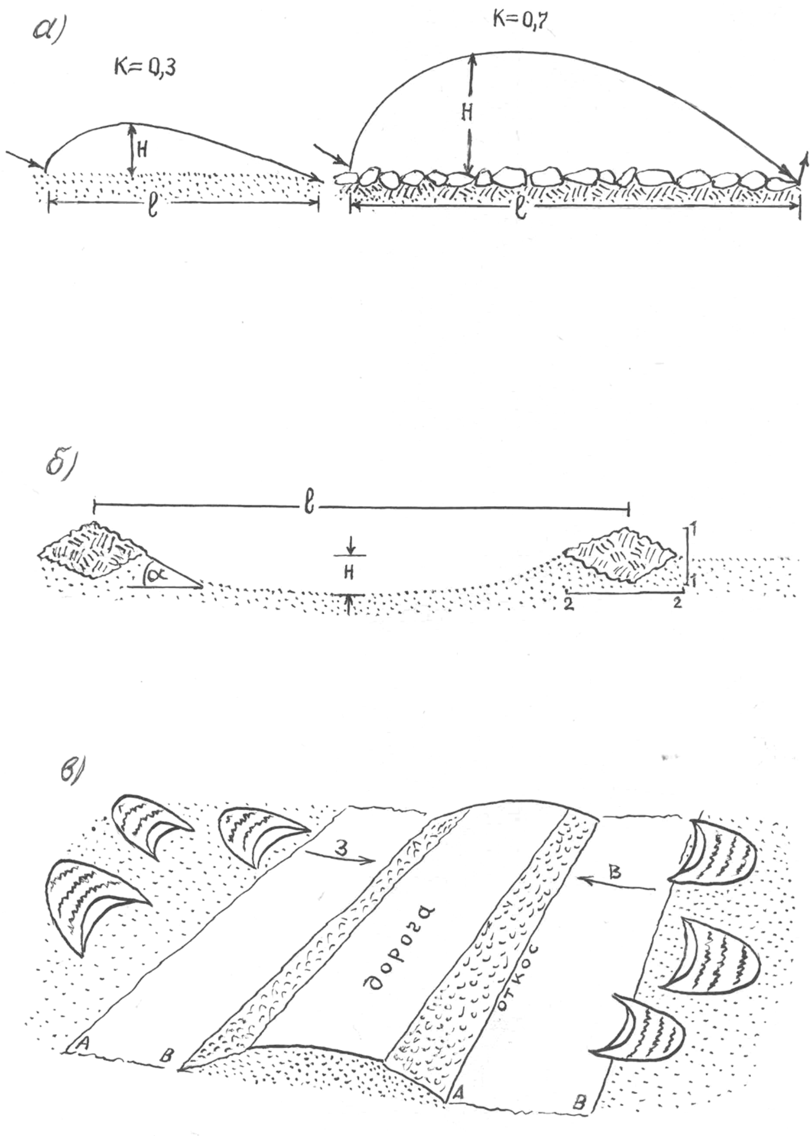

Fig. 11. Flight of a sand particle depending on the change in the coefficient of recovery (K = 0.3 for an unsecured sandy surface and K = 0.7 for gravel and crushed stone) a - height (H) and length (l); b - clay rollers, where 1-1 roller height 10 cm, 2-2 width equal to 20 cm; c - protection of the road according to an integrated method: road slopes covered with gravel-clay or crushed-stone-clay mixture, AB - rolls of clay or solid outline, blocking moving sand forms.

It is known from aerodynamics that with an increase in height from a sandy surface, the wind speed also increases. Therefore, it is desirable that the height of the jump of the sand particle be as high as possible, because in this case, the particle falls into the zone of increased wind speeds, and, therefore, the speed of the sand particle will also increase. And this is the main condition for the implementation of non-accumulation transfer of sand across the road without its accumulation (deposition) on the carriageway (23,24,25).

The most common and proven protective material is reed (Fig. 12). Practitioners have accumulated a wealth of experience in the use of various types of protections to protect against sand drifts and swelling from reeds. Very often mats up to 10 cm thick with sides of 1 x 2 m are made from reeds. We propose to change the mats knitting system so that it can be cut into three rather than two parts. In this case, there will be material savings and, in addition, the length of the mats obtained is quite sufficient for their installation even on the extreme rows of protections. In this case, the installation mats will have a height of 0.7-0.8 m. However, in some cases, it is still necessary to install locks from meter mats. Locks of this kind must be used in especially dangerous cases. In addition, the ten-meter thickness of the mat is somewhat overestimated. The mats can be made much thinner within 5-6 cm. This is quite enough, since the purpose of the protection is to stop the removal from the area adjacent to the base of the support, and not to prevent the transfer of sand passing by the support. By accepting these proposals on cutting the mats not into two, but into three parts of 0.7-0.8 m each, and reducing the density of two-meter mats by half to a thickness of 5 cm, it is possible to significantly reduce the cost of protecting the base of the supports from sand blowing. Reed circular defenses consist of a system of shields buried in the sand by 40 cm and standing at an angle (the upper part of the mat is inclined to the support) with a depth of 60 cm.

If the upright mat is deepened by 40 cm, the cross-sectional area of the excavation site for installing the shields can be considered equal to 0.16 m2. The slope angles in dry sand are 300, and in compacted or wet sand, the slope angle can reach 900, and, therefore, for convenience of calculation, you can take an excavation angle of 45°. In this case, the excavation area is equal to the product of the depth and half the width. The volume of excavated soil per linear meter will be 0.16 m3. Likewise, the excavation area for the installation of mats at a depth of 60 cm will be 0.36 m2, assuming that the slope angle is 45°. Accordingly, the volume of excavated soil per linear meter will be equal to 0.36 m3.

As mentioned above, to calculate the amount of excavated soil and determine the cross-sectional area of the ditch, we took the slope angle equal to 45°. In nature, the slope angle of dry loose sand is approximately 30°. In turn, the short-term slope angle of wet sand can reach 90°. However, in nature, sand is most often more or less dry. For different regions (sites) and seasons, the slope angle of dense, free-flowing and wet sand can vary greatly. So, for example, on the basis of our observations, we came to the conclusion that to simplify calculations, the slope angle can be taken equal to 45° with a small error. This means that when designing, the width of the ditch can be considered equal to its depth. Calculations must be made in accordance with this relationship. When installing boards vertically, deepening should be done for meter mats to a depth of 40 cm, and for mats with a height of 0.7-0.8 m by 30 or 40 cm, for half-meter mats - a depth of 20-30 cm. Inclined meter mats should be deepened by 60 cm, and shields of 0.7-0.8 m need to be buried by 50 cm, taking into account only the depth of the excavation.

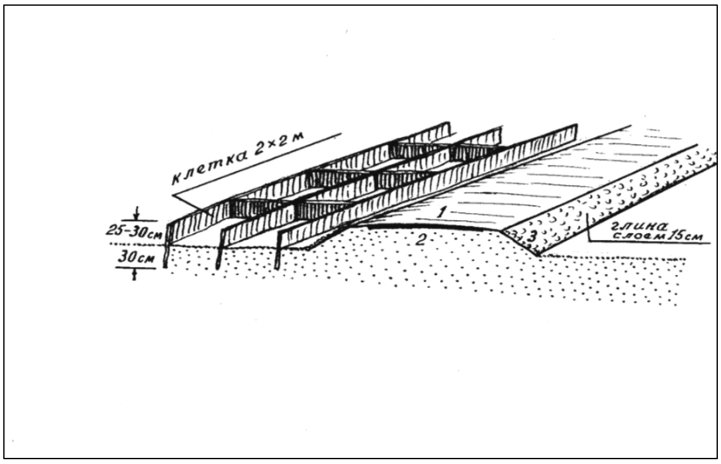

Fig. 12. Installation of cage protections along the road.

Selection of species and technology of planting vegetation to fix the sands.

The types of the corresponding tree and shrub species are selected taking into account their biological characteristics and are recommended by us taking into account changes in the depth of occurrence and mineralization (especially salinity) of groundwater.

On separate scattered sandy massifs, located among the developed lands, as well as in the zone of contact of the desert with oasis landscapes, we recommend sowing and planting of black saxaul, cherkez, kandym. The aforementioned areas are partially fixed by herbaceous vegetation and only need to take measures for the natural overgrowth of psammophytes with shrubs. In the rest of the desert ecosystems, it is mainly cherkez, kandym, white and black saxauls that are recommended. Everywhere on thin sands, sandy takyrs and the lower part of slopes and hillocks on the entire surface of small ridges, bridges, hillocks, cumulus sands, black saxaul, Richter's Cherkez and Kandym, small-fruited and densely bristle, are acceptable for planting. Here, on the upper third of the slope of the middle ridges, the middle and upper parts of the slope of large ridges, only white saxaul should be planted, given the thickness of the sandy deposits (36).

In places of intersection of large, high and medium ridges, lying on takyrs and takyr-like deposits on the upper obarchite part, it is advisable to use tree-like kandym, white saxaul, Paletsky cherkez for planting. On aeolian sands lying on loose sandy deposits of the pre-Amu Darya, it is necessary to use white saxaul everywhere.

In inter-ridge depressions, or thin sands near takyrs, on thin, small, medium bridges, it is advisable to plant kandym and cherkez.

On sands and other soils with similar non-flowing saline ground waters to varying degrees (depth 0-1.5 m), the following are acceptable: comb, poplar variegated or turanga, atriplex. On sandy loam sands with close (depth 1.5-2 m) fresh flowing groundwater (on the outskirts of irrigated lands), it is advisable to plant: white mulberry, apple tree, quince, grapes, Eldar pine, thuja, makliura. However, these plantations should be regularly watered for the first 2-3 years, and in places where the depth of groundwater is more than 3 meters - throughout the life of trees and shrubs. In areas with a close occurrence of groundwater adjacent to saline soils, saline depressions (depises), on saline soils with excessive moisture, we recommend planting atriplex, turanga, comb, eastern goose. They also need watering during the early years of vegetation and growth. In favorable years with an amount of precipitation that ensures a guaranteed vegetation of crops from plants, sand-strengthening plants are observed from 1 to 4 times in 10 years. Therefore, to obtain 100% survival rate, it is necessary to plant seedlings of desert plants (saxaul, cherkez, kandym) to water at least once a month (May, June, July, August) at the rate of 10 liters per hole in the evening and at night. Without watering, plantations in the sands give survival rate of 10-70%, depending on the conditions of the year and the place of their growth. For the entire growing season, 17 waterings are carried out (including: in spring 4, in summer 9 and in autumn 4 waterings). For each planted plant, 16 (on sands) - 20 (on clay soils) liters are given. At the same time, 270 (on sands) - 340 liters are consumed for each plant during the growing season. This volume of water is needed in the year of planting to wet the soil in a volume of 1 m3. In the second year of the growing season, it is advisable to increase the volume of the soaked soil to 1.5 m3. This method can be used to create multipurpose plantings on sands where mechanical protection is installed. The density of shrub seedlings when they are planted using mechanical protection is 3000-3500 pieces per hectare. At the same time, the density of planting for other purposes can be from 12,500 to 500 per 1 ha, and the layout is from 2x3 to 4x5 m, depending on the type of planting material and the purpose of the plantings being created. Dates, rates and depth of planting seeds are shown in table 6.

Table 6.

Name of plant	Depth of planting, cm		Sowing rate of unframed seeds, kg/ha		TSowing time	
	Sandy soils	**Sandy loam soils**	**Full**	**Half**	**Ashgabat-Bokurdak**	**Dashoguz-Shahsenem**
Black and white saxaul	3	1,5-2	6	3	February - March	March - April
Paletskiy Cherkez	3	2	6	3	-//-	-//-
Large-fruited Kandyms (tree-like, jellyfish head)	7-9	5-6	9	4,5	-//-	
Small-fruited Kandyms (high, Turkestan)	4-6	3,5	7	3,5	-//-	

Methods of fixing technogenic sands by local psammophytes.

Strip plantations are created on the outside of the plots where mechanical protection is installed and psammophyte shrubs are planted. The structure of strip plantings changes depending on the habitat conditions (Fig. 13). They are determined by the following criteria: the type of aeolian deposits, the degree of vegetation on the sand surface, the depth and degree of groundwater mineralization, etc. Strip plantations are a culture of psammophytes planted or sown in strips. Their width ranges from 4-6 to 10-20 m. To create strip plantings, pre-planting soil preparation is carried out, depending on the sod horizon. It is performed in the fall. Plowing is carried out to a depth of 25-27 cm with a 4-body tractor plow PN-4-35. The width of the processed strip depends on the width of the projected strip. On semi-overgrown sands, pre-planting or pre-sowing soil preparation is carried out selectively - only in places where sod is present.

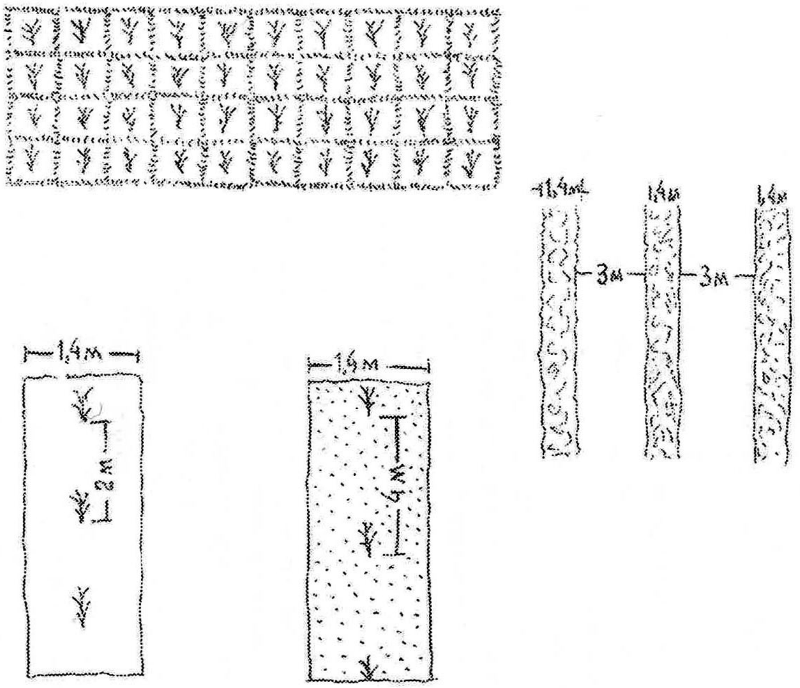

Fig. 13. Method of sowing seedlings and seeds in plowed strips

The wings are a system of 3 plowed strips, each 1.4 m wide, placed every 3 m. The wings, just like **linear** plantations, are created perpendicular to the prevailing winds, depending on the habitat conditions. On aeolian sands with favorable conditions for vegetation germination, the distance between the wings should be 40 m, and in areas with satisfactory conditions - 30 m and with unfavorable conditions - 20 m (Fig. 14).

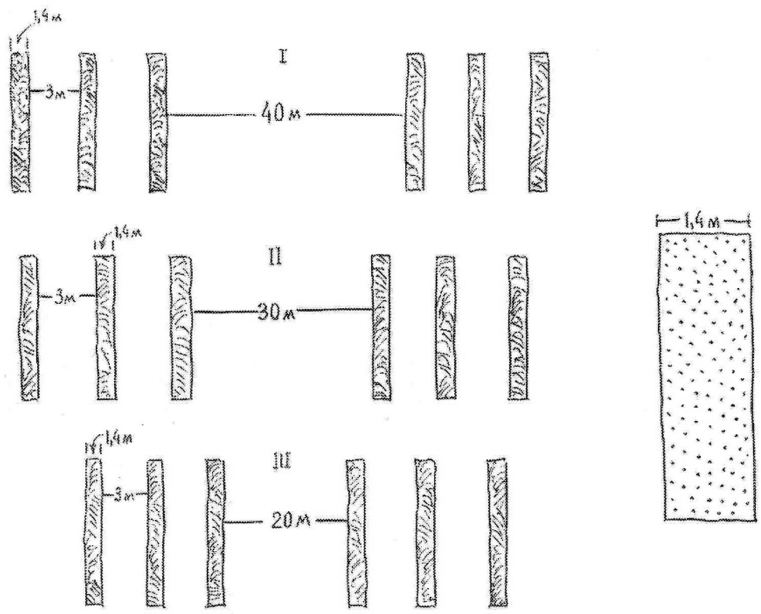

Fig. 14. Winged method of planting vegetation.

Phyto-reclamation works, according to their importance and purpose, can be divided into the following conditional groups:

a) Carrying out of "Plantings of the first zone", i.e. directly adjacent to the bed of linear engineering objects: roads and railways. This is the most dangerous, heavily drifted and blown out zone, since the relief and vegetation in it are disturbed by the planning during the construction of these facilities. "Plantings of the first zone" should be created in conjunction with the installation of standing (cellular and ordinary) defenses from reeds or other plant material.

These plantings are located at a distance of up to 60 m on both sides of the engineering facility. They are created by sowing and planting sand-strengthening bushes: saxaul, cherkez, kandym by mechanical protection on moving areas and the lower 2/3 of the dune. And the upper 1/3 of the dune is left bare. It must be secured with mechanical and other protections after flattening it out by the wind. The process of leveling the upper part of the dune, depending on the wind regime of the territory, the height of the dune, aerodynamic conditions, can be completed in a few months or weeks. On a leveled surface, it is necessary to quickly establish the types of mechanical protection. Sowing and planting of sand strengtheners is carried out at the optimum time.

"Plantings of the first zone" should be created locally, not only in small or large areas, but in places where sand fields and chains are spread - a continuous strip on both sides of engineering objects.

b) Creation of "Plantings of the second zone", i.e. zones where vegetation and sand relief have been greatly altered and partially leveled. "Plantations of the second zone" should be created in conjunction with the installation of standing (cell and row) protections from reeds or other plant material. Sowing and planting should be carried out in an insignificant amount on mechanical protection, but mainly on weakly brought in small bare patches of mobile sand. The width of these plantations can be 60-150 m.

c) Creation of "Introzonal plantings" is carried out by the method of sowing and planting salt-tolerant (halophytes) and salt-drought-resistant (haloxerophytes) plants. This zone covers bare, disturbed and dune sands lying on salt marshes, in places of excessive moisture, irrigated lands, on salt marshes, hollows, ravines and other depressions.

Work can be carried out with the installation of mechanical protections, and in poorly drifted areas, only by planting plants. To create them, one should also use rocks that can grow in conditions of excessive moisture in the places where filtration lakes exit. They are created against the background of previous landings of the first zone.

d) Creation of "Plantings of the third zone". They are located on the border of the Lower Amudarya and Prikopetdag oases with the Karakum desert. They are created in a strip with a width of 100-500 m without the installation of mechanical protections. Taking into account the relief, soil types, sowing or planting, or a combination of both, can be done. On the ridge takyr complex, plantations are created on a strip up to 1000m wide; on semi-overgrown and broken sands - up to 1500m wide. Their function is as follows:

e) Promotion of natural overgrowing of intra-oasis and oasis sands by strictly protecting seed-bearing shrubs, and in places of insufficient density - planting seedlings and sowing seeds.

f) Creation of plantings of decorative, fruit, berry species for the purpose of landscaping and the development of gardening at related engineering facilities: bus stops, parking lots, cafes and at service points and gas stations.

g) Creation of forest stands, strips and parks for recreational purposes near recreation sites.

Atmospheric precipitation creates favorable conditions for natural regeneration of vegetation and can be observed once every 10 years. Phyto-reclamation works are carried out in several stages:

- soil preparation (only on soddy sands, on takyrs, salt marshes and other dense and wind-resistant surfaces);
- selection of an assortment of tree and shrub species, sowing seeds and planting seedlings or cuttings, watering and protection of crops from pests;

- On the plots of location of recreation sites, service points and gas stations, we recommend planting the following species: thuja, pine, apple, fig, mulberry, poplar;
- On the borders of irrigated lands - planting of wild oleaster, turanga, etc. with watering for the first 2-3 years;
- On sandy shallow sediments, promote its natural regeneration through strict protection of vegetation;
- On the brought in areas - local installation of mechanical protections with planting of black saxaul, kandym, cherkez on them. At a distance from engineering facilities, sowing seeds (mainly in areas where the thickness of aeolian deposits on salt marshes, takyrs, fallows is more than 1 m). Density of planting and sowing of seeds is regulated depending on the forest growing conditions and the degree of bareness;
- At the intersection of sandy ridges and on slopes, in places where sandy overgrown ridges are cut, - continuous installation of protections with planting shrubs.

Conduct selective fixing of dunes on both sides of linear objects at a width of 20-40 m, up to 60 m long. Preliminary flattening of steep slopes in places where high sandy ridges are cut. Fastening of slopes in places where aeolian ridges are cut with the obligatory installation of mechanical protections. The width of the protective inslattations is 20-40 m, the length is sometimes up to 200 m. The lower 2/3 of the windward slope is fixed on high, bare sand forms. Small dune forms are locally fixed in depressions and cells. On small bare areas of semi-overgrown sands, selective planting of shrubs without the installation of mechanical protections is carried out. Fastening of slopes in places of cut of transverse or longitudinal (rarely) sand ridges and lintels.

Securing the slopes of the earthen embankment of the road with clay, crushed stone, especially in inter-ridge depressions. Continuous protection from both sides on straightening segments, i.e. violation of the former natural relief. Solid protection on both sides of linear objects at the intersection of dune fields. In some places, it is possible to plan and install mechanical protections in a strip up to 20 m wide. For mechanical protections, planting and sowing at a full rate of seedlings (1750 pcs / ha) and seeds (3-4.5 kg / ha). In the first months, the inter-ridge depressions are left without mechanical protection until they are filled with aeolian material. Prior to the leveling of the relief on the lower 2/3 of the ridges, located 30-60 m from the linear objects, the installation of mechanical protection and a full complex of sowing and planting is carried out. At a distance of up to 200-300 m from the strip of the linear object, depending on the conditions and the degree of bare sand, carry out free sowing of psammophyte seeds without plowing the surface. Installation of protections is carried out when crossing sandy ridges, hillocks, disturbed during the construction of the subgrade. At a distance from the road lane up to 200-300 m, it is recommended to sow psammophyte seeds.

In areas of sand not disturbed by planning work, the planting of desert bushes should be carried out selectively on gentle slopes strongly dissected by blowing ulcers at a distance of 60 to 150-200 m.

In places where sandy deposits are spread:

a) In the presence of seed-bearing shrubs, promote the natural regeneration of trees and shrubs by creating a protection strip of 1000-1500 m;

b) In the presence of introduced areas, installation of protection with sowing a full norm of seeds of kandim, cherkez and black saxaul.

c) at the intersection of single medium and large mounds and other forms - flattening of large slopes in places of cut, installation of mechanical protections with planting of kandym, cherkez and saxaul. Stocking density depends on the degree of exposure and mobility of the sands.

On sandy deposits:

a) On poorly drifted sections of the route, it is necessary to selectively install ordinary protection and sow half of the seed rate of seedlings (1.7 thousand pieces/ha) of saxaul, Cherkez and kandim;

b) On heavily drifted sections of the road on bare ridges and dunes, it is necessary to install mechanical and other protections and plant seedlings of psammophyte shrubs (white saxaul, Circassian, kandym).