

Sustainable development of Turkmenistan in the context of climate change

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Abstract. The geographical location of Turkmenistan makes it particularly vulnerable to climate change. Global warming threatens to impact key aspects of the country's socio-economic development, especially in sectors such as water management, agriculture, and healthcare. Consequently, adapting to climate change has become a primary focus of the National Strategy of Turkmenistan on climate change. This paper highlights the critical role of ongoing adaptation measures—such as urban greening and improved water management systems—to compensate for potential irrigation water shortages caused by climate change. It also emphasizes the importance of developing strategies to enhance the use of return waters, which will contribute to reducing water resource scarcity, improving environmental conditions, creating new jobs, and strengthening the standard of living for the population.

1 Introduction

In the modern world, close attention is focused on environmental issues, without solving them it is unthinkable to focus on the further stable development of mankind. Cooperation in the field of ecology is one of the key aspects of the foreign policy of Turkmenistan, which initiates constructive solutions to global environmental problems for the sake of the well-being of the present and future generations of the planet.

Turkmenistan takes an active part in international cooperation with authoritative international organizations, primarily the United Nations, the European Union, the Global Environment Facility, and others, in the implementation of joint projects aimed at solving pressing environmental problems that concern all of humanity, such as conservation and restoration of water and other natural resources, combating desertification, land degradation, global warming, climate change.

Issues of combating desertification, drought, sand, and dust storms occupy an important place in the state development programs of Turkmenistan. Reducing the risk of these phenomena and mitigating their consequences will contribute to the sustainable development of the country's economy in the face of climate change and increasing water resource shortages. Turkmenistan is based on numerous national strategic documents and programs.

In October 2016 Turkmenistan ratified the Paris Climate Agreement, and a new National Strategy of Turkmenistan on climate change was prepared in 2019 [1].

The new edition of the strategy meets the objectives of the Program of Socio-Economic Development of Turkmenistan for 2019-2025 and the Program of Socio-Economic Development of Turkmenistan for the period 2011-2030 [2], The National Strategy for the Development of Renewable Energy in Turkmenistan until 2030, the State Energy Saving Program for 2018–2024, which includes several measures to combat climate change that meet the realities of today.

2 Materials and methods

2.1 Study area

Turkmenistan is situated in the western part of Central Asia and is a landlocked country. It is bordered to the north by Kazakhstan, to the northeast and east by Uzbekistan, to the southeast by Afghanistan, and to the south by Iran. To the west, the natural border is formed by the Caspian Sea, which also serves as a boundary with Azerbaijan. The total area of Turkmenistan is 491.21 thousand square kilometers, extending 1,100 km from west to east and 650 km from north to south. The country is characterized by a developing economy, exhibiting a stable annual gross domestic product (GDP) growth rate of 6–8% in recent years, with a population exceeding 6 million people [3].

Among the Central Asian countries, Turkmenistan features the flattest terrain, with approximately 80% of its land comprising deserts and semi-deserts. The remaining 20% consists of mountains, foothill plains, and hills. The primary relief forms of the region are a result of the area's geological history and are influenced by physical and geographical factors. The flat regions generally slope toward the Caspian Sea, from east to west.

Geographically, the entire flat area of Turkmenistan is part of the Turan Lowland, which can be categorized into three landscape types:

- a) Tertiary plateau,
- b) Sandy deserts,
- c) Loess foothill plains.

The Tertiary plateau includes the Krasnovodsk plateau, as well as the extremities of Ustyurt and Mangyshlak. The sandy deserts encompass the central, southeastern, and Zaunguz Karakum regions. The loess foothill plains are located at the northern base of the Kopetdag and Paropamiz ranges. To the south, the sandy deserts transition into the hills and foothills of the Kopetdag, which are medium-altitude mountains reaching up to 2,942 m above sea level. North of these ridges lie the separate Small and Big Balkhany ranges. Adjacent to the Kopetdag from the north is a foothill plain that connects with the Caspian lowland plain to the west [3].

2.2 Research methodology

Turkmenistan experiences one of the harshest climates in Central Asia, characterized by a sharply continental climate with high summer temperatures and low precipitation. Summers are hot and dry, typically lasting from May to September, while winters are generally mild and dry. Precipitation levels vary significantly across the country, ranging from approximately 300 mm in the Kopetdag region to as little as 80 mm in the northwest. The highest recorded surface temperature in Turkmenistan exceeds 80°C, particularly in the Karakum Desert.

The limited rainfall and high evaporation rates place significant pressure on the country's water resources. Sandstorms are a common phenomenon, occurring between 35 and 67 days each year, with some years experiencing up to 113 days of storms. The average annual wind speed across the plains is measured at 3.2–4.2 m/sec, which contributes to both desertification and the frequency of dust storms [3].

3 Results and discussion

Turkmenistan's geographical location makes it particularly sensitive to climate change. Studies indicate that Central Asia, and Turkmenistan in particular, is expected to experience further climate warming, characterized by rising air temperatures and decreasing precipitation, as well as an increase in the frequency and intensity of natural hydrometeorological events. These changes may have significant implications for many aspects of the country's socio-economic development. Consequently, adaptation to climate change has become a primary focus of Turkmenistan's National Strategy on Climate Change.

Global warming can profoundly affect various sectors, particularly water management, agriculture, and healthcare. Additionally, there will be significant impacts on flora, fauna, forests, and the availability and quality of water, soil, and land resources. Intensive economic development and population growth are likely to lead to increased water consumption, compounding the current water scarcity issues. As a result, climate change is expected to decrease available water resources and diminish their quality [3].

The "National Strategy of Turkmenistan on Climate Change" outlines a phased transition of all key sectors to meet environmental safety standards. This strategy prioritizes the development of high-tech industries and aims to create conditions conducive to a "green economy," which is essential for the country's overall infrastructure and life support systems. Substantial efforts are also underway in nature conservation, biodiversity preservation, and the protection of natural landscapes [4] [5].

A critical area of adaptation involves implementing measures to enhance agricultural resilience to climate change. The National Forestry Program guides policies and actions in the forestry sector, addressing the heightened risks of wildfires and pest infestations due to climate change. Nationwide urban greening initiatives are foundational to the sustainable management and protection of forests.

Annual nationwide greening campaigns are held in Turkmenistan, resulting in the planting of over 35 million diverse tree species. A "Green Belt" has been established around the capital, Ashgabat, to shield the city from dust storms, improve air quality, and enhance biodiversity. In 2020, Turkmenistan joined the international "Trees in Cities" program, during which 25 million seedlings were planted in urban areas [3]. This initiative is a global campaign initiated by the United Nations Economic Commission for Europe to bolster climate action in cities. Moving forward, the country will intensify its efforts to adapt to climate change through extensive greening plans [5].

The filling of the artificial Turkmen lake "Altyn Asyr" has enabled the irrigation of 11 million hectares of desert pastures and improved the reclamation of 440,000 hectares of irrigated land. The discharge of drainage water into the Karakum and Amu Darya deserts has been completely halted, and a forest spanning 20,000 hectares has been planted in the Botendag area [4].

Global climate change is closely linked to the rapid rise in greenhouse gas concentrations in the atmosphere. Turkmenistan is committed to reducing greenhouse gas emissions, setting a target of a 20% reduction by 2030 compared to 2010 levels. The country is also supporting international efforts to curb greenhouse gas emissions and is systematically moving toward

the adoption of modern, environmentally friendly, and resource-saving technologies in construction. A notable example is the innovative "Smart City" project in Arkadag.

Arkadag is located 30 kilometers southwest of Ashgabat in the foothills of the Central Kopetdag Mountains, in one of the oldest regions of Turkmenistan. To preserve the area's natural beauty, the "Smart City" concept incorporates extensive use of green technologies through the implementation of digital and intelligent systems. These technologies are crucial for fostering an ecological economy and cultivating an ecological culture within society.

The development of "Smart Cities" worldwide aligns with the UN's Agenda for 2030 and supports the achievement of the 17 Sustainable Development Goals (SDGs). This includes enhancing quality of life, ensuring access to education and digital information, preventing negative environmental impacts, promoting a green economy, and creating jobs with favorable working conditions.

The Arkadag Smart City project is one of the largest in the region, integrating the global principles of "Smart City" development with Turkmen culture. The construction of Arkadag is divided into two phases. The first phase involved the completion of 336 buildings and structures, including 258 residential buildings with high comfort, 11 public buildings, 25 government facilities, 19 educational institutions, 9 medical and sports centers, and 14 engineering systems. This scale of development reflects the project's ambition.

The second construction phase includes 5 secondary schools with 720 seats each, 9 kindergartens with 320 seats, a health center, fire service buildings, 151 additional structures (including 126 residential buildings with high comfort), a park, modern communication areas, and important infrastructure such as railway and road stations, an automobile complex, and facilities for modern medical products and equipment.

The Arkadag Smart City project is also part of the initiative to develop sustainable, green, and climate-friendly cities with innovative solutions within the region of the Organization for Security and Cooperation in Europe, demonstrating international recognition of its accomplishments.

The "Smart City" concept emphasizes the integration of information, communication, and energy-saving technologies across urban economies, the attraction of qualified personnel, and an overall increase in urban efficiency and quality of life. Environmental protection is a priority and implementing the best technologies in water conservation, energy efficiency, transportation, and sustainable building practices is essential to creating an eco-friendly urban environment [5].

In response to climate change, one sustainable irrigated agriculture development method in Turkmenistan is the reuse of collector-draining waters [4] [5]. In the Arkadag Smart City, a meticulous approach to water resource management is evident. For the first time in Turkmenistan, irrigation water is being managed separately from drinking water. Rainwater inlets and a comprehensive collection network have been installed along all roads, where collected water is treated and directed into settling tanks.

A drainage system is also integrated into the urban infrastructure to lower the groundwater table. The collected water is settled and treated for reuse. In the context of water shortages, return water is a vital reserve that can help meet national economic needs. Utilizing this water for irrigation offers several advantages. It conserves water resources by reducing reliance on the Karakum River. It eliminates the need for coagulation and disinfection, saving on chemical reagents. In the Arkadag Smart City, water-saving technologies are exclusively employed for irrigation, including. Drip Irrigation: This method delivers water directly to the root zone of crops through a system of pipes, allowing for slow watering (typically no more than 0.02 m³ of water per hour per 1 m²). This method minimizes water loss through evaporation and runoff, with over 90% of moisture absorbed by crops.

Sprinkler Irrigation: This method distributes water from above onto the soil surface using sprinklers, breaking the water flow into small droplets. It is especially suitable for irrigating flowers, grass, and shrubs.

Enhancing the efficiency of irrigation systems is crucial for conserving significant amounts of water, thereby compensating for the water resource shortages posed by climate change. Transitioning from traditional to modern irrigation methods, such as drip and sprinkler irrigation, has demonstrated potential water savings of 30-40% [5] [6].

In the landscaping efforts of the Arkadag Smart City, a scientific approach guides the selection of tree species based on several criteria, including:

- Drought resistance
- Tolerance to extreme temperature variations
- Year-round oxygen release
- Dust retention capability
- Salt tolerance
- Aesthetic qualities.

4 Conclusions

Turkmenistan's response to climate change is multifaceted, focusing on greening urban areas, improving water management, and adopting sustainable agricultural practices. These measures will help mitigate the impacts of climate change, reduce water shortages, and improve the environment, thus contributing to the population's well-being. The country's commitment to international climate goals, including the Paris Agreement, highlights its proactive role in addressing global environmental challenges.

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