CSK Journal of Earth, Environment Science and Agricultural Research
Research Article
Volume 2 | Issue 1

Peculiarities of the Influence of Mountain Reservoirs on The Formation of Coastal Districts Microclimates

Normatov I[*], Rahimzoda A[1], Saburova G., Shermatov N.

[1]*Institute of Mathematics of the National Academy of Sciences of Tajikistan*

[*]**Corresponding author:** Normatov I, Institute of Mathematics of the National Academy of Sciences of Tajikistan, Tajik National University.

Received: 25-Jan-2025 **Accepted:** 31-Jan-2025 **Published:** 06-Feb-2025

Citation: Normatov, I., Rahimzoda, A., Saburova G., Shermatov. N. (2025). Peculiarities of the Influence of Mountain Reservoirs on The Formation of Coastal Districts Microclimates. J of Earth, Envi Sci & Agri Res, 2(1): 01-12.

Abstract

A characteristic feature of the Central Asian (CA) region is the uneven distribution of water resources, which determines the interdependence of the five countries of the region in their joint use. The uneven distribution of water resources and the difference in the geographical location of the zone of formation and dispersion of the main water arteries is caused by the orography of the region, which is characterized by mountain-valley combinations. The water resources of the CA region are mainly formed in the headwaters of the Transboundary Rivers of the region and about 90% of them are used for irrigation of agricultural lands of the downstream countries. The construction of reservoirs is first and foremost a disruption of the natural flow of a watercourse to which the components of the ecosystem have been adapted for many years. In order to ensure the smooth operation of economic and especially agricultural facilities and to develop mechanisms for their adaptation to the climatic conditions created under the influence of reservoirs, it is important to carry out research and monitoring of climatic conditions in areas under the influence of reservoirs. Pearson's and Student's linear correlations, statistical and comparative methods of analysis of dynamics of hydrometeorological parameters were used to process the observed data and establish correlation dependencies. Database of observation results at the stations 'Dangara', 'Yavan' were used.

Keywords: Nurek Reservoir, Evapotranspiration, Correlation, Mountain, Precipitation, Temperature, Drought.

Introduction

The creation of large hydroelectric power plants on rivers leads to major changes in their natural flow and hydrological regime. As a result of the regulating effect of the reservoir, the river flow in the lower reaches becomes more uniform throughout the year. The regulating influence of reservoirs affects significant stretches of the river downstream of the dams and extends to the estuary. Conventionally, it can be assumed that the length of the lower reaches is determined by the limit of the restoration of the natural hydrological regime (mainly under the influence of large tributaries) [1-3].

The main function of reservoirs is to supply water to large areas of agricultural land. In addition, reservoirs fulfill ecological functions and contribute significantly to the biodiversity of flora and fauna. The rapid increase in the number and area of reservoirs over the last half century is related to the fulfillment of these important functions. Over the last 30 years, the area of reservoir mirrors has increased significantly [4, 5].

However, it should be noted that the increase in the surface area of water mirrors is associated with evaporation processes and thus with changes in the microclimate of areas adjacent to reservoirs [6]. It has been calculated that 40% of the water volume of reservoirs, which is obtained by multiplying the evaporation rate by the surface area of the reservoir [68], is used for evaporation every year, and this process is significant in arid and semi-arid areas [4, 9, 10].

Despite the problems in obtaining reservoir surface area and evaporation rate data, accurate estimates of surface area and evaporation rate are still needed to accurately quantify reservoir evaporation. To date, reservoir surface area is usually determined using field measurements or remotely sensed imagery [11]. Field measurements are mainly based on the reservoir surface area curve [12], but this approach is time and labor intensive. In addition, surveying is difficult in some regions with harsh natural conditions, resulting in a lack of accurate reservoir data. In contrast to traditional field methods, remote sensing has the advantages of wide coverage, long time sequences and ease of data collection.

In particular, Landsat products have the advantage of continuous coverage over time and high spatial resolution (30 m). In addition, Google Earth Engine (GEE), a cloud-based processing platform for Landsat products, has emerged in recent years as a good option for large-scale and long-term analyses of reservoir surface changes [13-16]. Although the Penman method [17] can calculate evaporation more accurately by inputting a number of evaporation parameters, meteorological data for evaporation calculation are often not recorded from the reservoir surface. In addition, reservoirs have a heat storage effect, which means that the calculated evaporation results may not reflect the actual evaporation. Many studies have been carried out on these two issues [18-22]. In recent years, previous results have been systematically integrated and improved to calculate evaporation from the water surface more accurately. The improved results have been verified and widely used to calculate evaporation from reservoirs [7, 8].

As dam construction continues to expand rapidly around the world, there is a need to assess and mitigate the social, economic and environmental impacts of natural water impoundments. Worldwide, more than 3700 large dams are currently in the planning or construction phase, which are expected to reduce the number of free-flowing rivers on Earth by 21% [23]. The majority of planned hydropower projects are located in developing countries. The importance of the role of reservoirs in significantly reducing greenhouse gas emissions into the atmosphere through the production of green electricity is particularly felt today in the context of the aggravation of the climate change problem [24-28]. There is no denying some negative aspects of dam construction, such as vegetation change, warming of the construction areas, which are listed in the category of large anthropogenic pressures [29]. However, reservoirs protect downstream populations from floods and contribute to the creation of a favorable environmental situation [30].

In addition, the combination of high-resolution meteorological data [31,32] with calibrated and validated hydrological models is an important tool for determining the water quantity [33-37] and quality [38-42] of the basin for the study of hydropower plants, a potential that can be provided. The adverse effects of dams can cause various physic-chemical processes in the environment that lead to the disruption of ecosystem components [43-45]. A reduction in vegetation cover disturbs the thermal balance of an area by increasing the proportion of reflected solar radiation [30]. Finally, it affects atmospheric processes by increasing water vapor in the Earth's surface layer [46, 47]. The generalization of these processes caused by the construction of reservoirs is called the influence of reservoirs on the formation of the atmosphere.

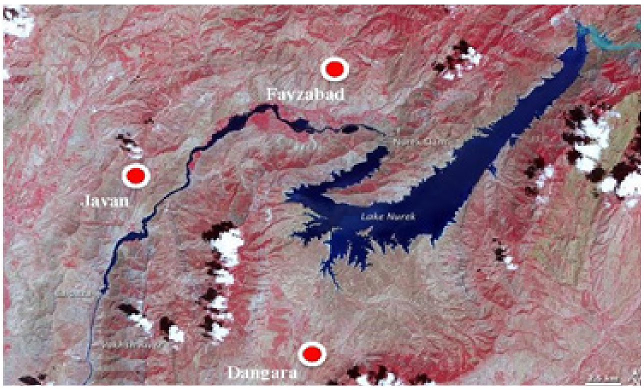
In determining the influence of reservoirs on the microclimate of the area, an important problem is the radius of influence, which depends on the volume of the reservoir and the surface area of the water mirror. In recent years, a number of publications have appeared on the influence of reservoirs as a climate-forming factor on the climate not only of individual districts, but also of regions [48, 49-52]. These studies find increased humidity and reduced temperature amplitudes in areas adjacent to artificial reservoirs, with insignificant variations in precipitation that become less pronounced with increasing distance from the reservoirs.

Furthermore, the effect is more pronounced in Mediterranean and semi-arid climates than in humid climates [48]. A number of publications reflect the effects of reservoirs on aquatic and riparian plants [53] [71] and biodiversity loss [54, 55].

Thus, the above work provides further evidence of the impact that large dams will have on the local climatic conditions surrounding them in the future. The predominance of dry and warm meteorological regimes in a particular region characterised by subarid conditions is predicted to be exacerbated by climate change. Changes in climatic conditions caused by reservoirs contribute to the mitigation of large-scale warming and drought trends, and indirectly to the reduction of greenhouse gas emissions through renewable energy production [56-58].

Materials and Methods

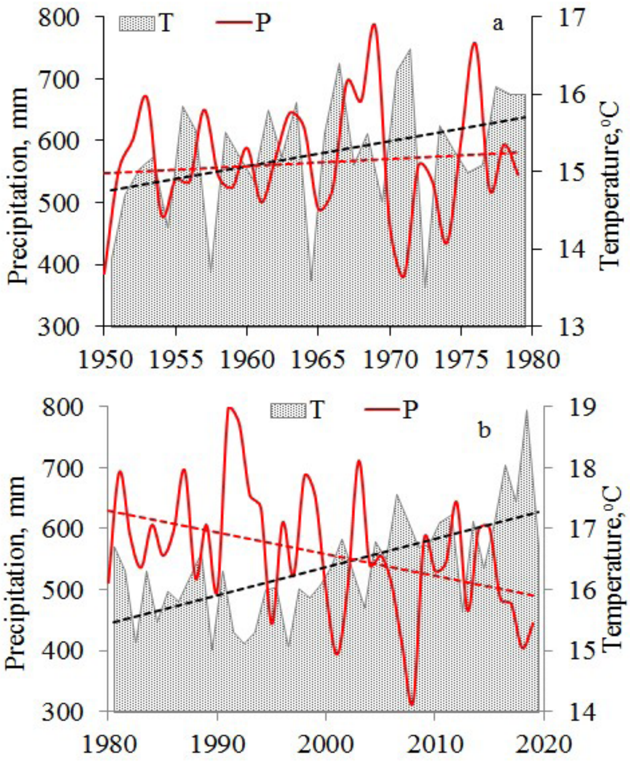
The operation of a large hydraulic structure such as the Nurek Hydropower Plant with a reservoir will make appropriate adjustments in the natural course of development and life activity of the components of the ecosystem. The Nurek reservoir, with a total water volume of 10.5 km3 and a water surface area of 98 km2, is subject to intensive water loss due to evaporation in the warm months of the year under climatic conditions characteristic of arid and semi-arid regions. Taking into account the dominance of mountain-valley circulation processes characteristic of mountain orography, it can be assumed that it can have a significant impact on the meteorological conditions of the area. The reservoir depth of more than one hundred meters with a normal retention level of more than nine hundred meters, which was achieved in 1983 at the beginning of the construction works since 1961, has a significant impact on the thermal regime, hydrochemical and mineralogical composition of the Vakhsh River after the dam [3]. This paper presents the results of research on the impact of the Nurek reservoir on the microclimate of the coastal agricultural areas of Dangara (660 m a.s.l, 38o10' N, 69o32' E), Faizabad (1215 m a.s.l., N, 38o15' N, 69o32' E) and Javan (632 m a.s.l., 38o32' N, 69o05' E). Fig. 4.1 shows a map of the study areas in relation to the Nurek reservoir and its geographical location.



https://earthobservatory.nasa.gov/ Figure 1. Location map of the Nurek reservoir and coastal areas (Dangara, Yavan, and Faizabad).

Results and Discussion

after the operation of the reservoir. A characteristic **Dangara district**. In order to determine the influence of feature of the temperature dynamics is that the trend of the Nurek reservoir on the climatic characteristics, the its change takes on a more pronounced growth character temperature changes in Dangara district for the period after 1980 (Fig.2, a, b). This can be seen by comparing 1950-2020 were considered for the periods before and the coefficients of determination for the two periods.



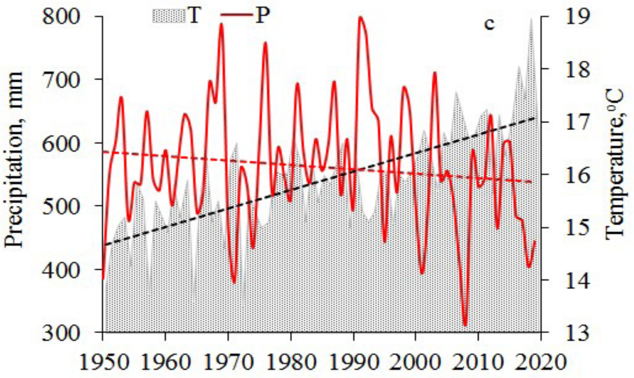


Figure 2. Pattern of variation of mean annual temperature and precipitation in Dangara district for the periods: 1950-1980 (a), 1990-2020 (b) and 1950-2020 (c).

The temperature dynamics of the Dangara district for the long-term to the annual long-term for the period under period 1950 - 2020 is presented in Fig.3, as the ratio of consideration. The increasing trend of the temperature the difference between the annual mean and the annual dynamics in the Dangara area from 1950 to 2020 runs at a rate of 0.05 oC (Fig.3). The temperature dynamics of extreme, the transition from the 1950-1979 regimes to the Dangara area for the period under consideration is the 1980-2020 regimes, occurs, as can be seen from characterised by two equations describing its changes for Fig.3, in 1980, the beginning of the Nurek reservoir the periods 1950-1979 and 1980-2020. The temperature operation.

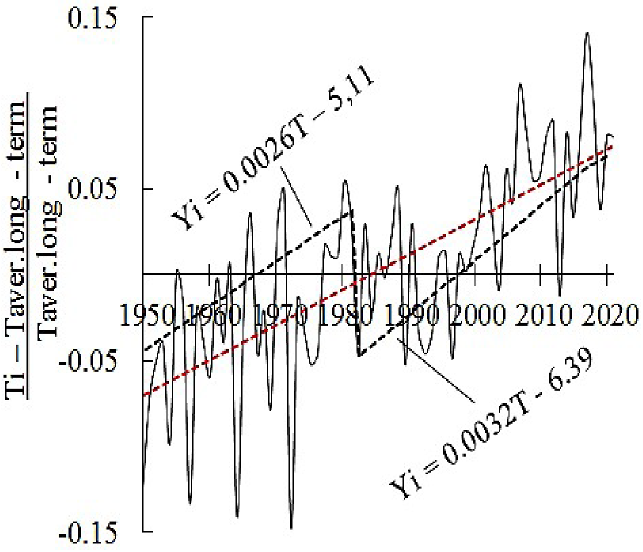


Figure 3. Ratio of annual mean and annual long-term temperature difference to annual long-term temperature and temperature trend for Dangara district before and after reservoir construction.

The precipitation extreme, i.e. the transition from the the period under consideration, the dynamics of regime of change 1950-1980 to the regime of the period atmospheric precipitation in the

Dangara district is 1981-2020, occurs in 1983, as can be seen in Fig.4. For characterised by a decreasing trend.

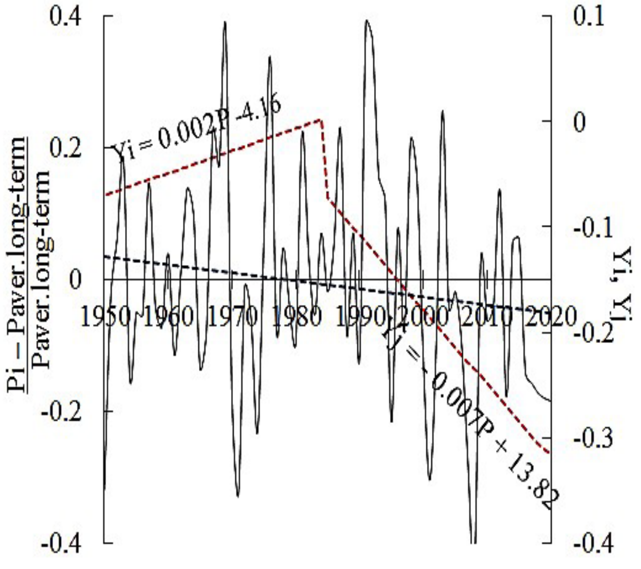
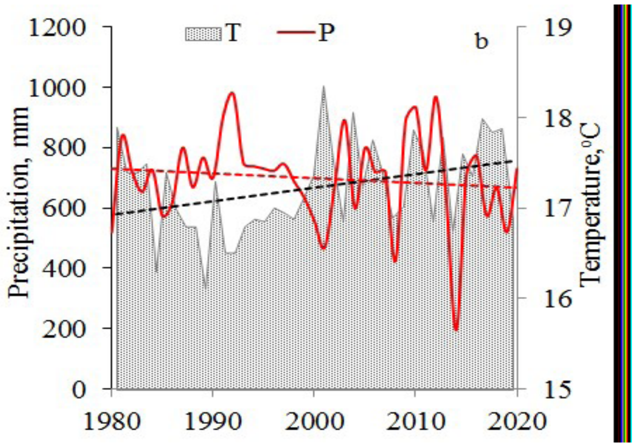


Figure 4. Ratio of annual mean and annual long-term precipitation difference to annual long-term precipitation and precipitation trend for Dangara district before and after reservoir construction.

Yavan District. The elevation of the Yavan district is 678 m a. s. l., i.e. below the elevation of the Nurek reservoir (more than 800 m a.s.l). It is logical to assume that water vapor by molecular weight should sink downwards and thus provide Yavan district with sufficient precipitation. The dynamics of precipitation changes for the periods before and after the construction of the reservoir and for the whole period 1950-2020 is shown in Figure 6. As can be seen from Figure 6, precipitation in Yavan has maintained a weak decreasing trend throughout the observation period. It can be assumed that in the absence of the reservoir, the decreasing trend of precipitation would be accelerated.



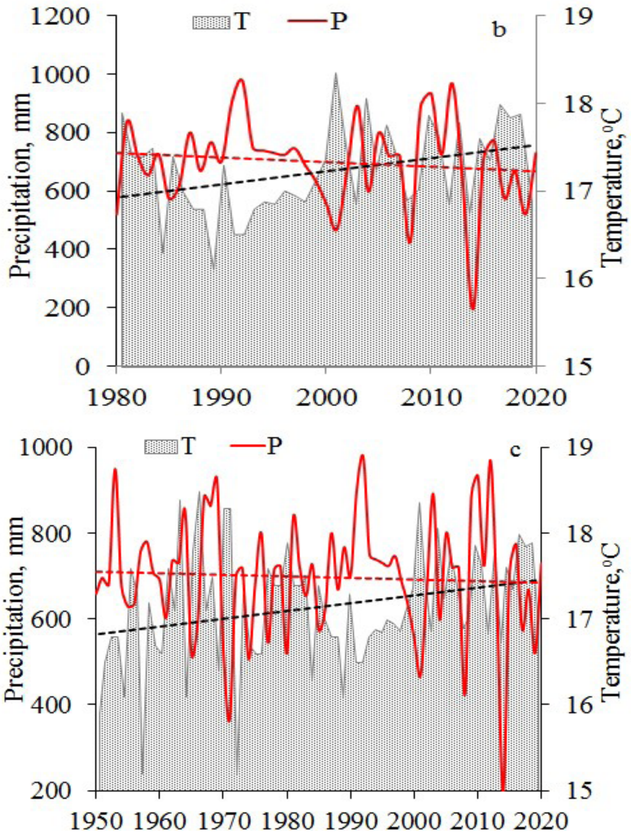


Figure 5. Pattern of variation of mean annual temperature and precipitation in Yavan district for the periods: 1950-1980 (a), 1990-2020 (b) and 1950-2020 (c).

The dynamics of temperature change in Yavan district in relation to the annual long-term is shown in Fig.6. The temperature dynamics in Yavan district from 1950 to 2020 has an increasing trend with the appearance of an extreme in 2004. According to our assumption, the accumulation of humid air masses caused by the Nurek reservoir becomes a kind of obstacle for the temperature increase in Yavan district.

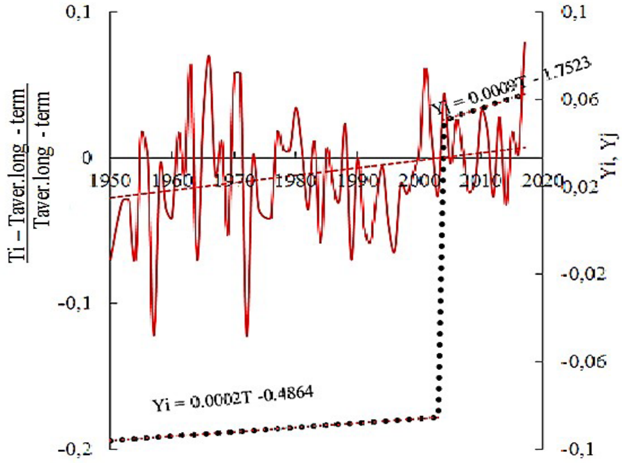


Figure 6. Ratio of annual mean and annual long-term temperature difference to annual long-term temperature and temperature

trend for Yavan district before and after reservoir construction.

Atmospheric precipitation in Yavan district has 2020. Fig. 7 shows that after 1983, there is a weakening maintained a decreasing trend over the period 1950 - of the decreasing pattern of precipitation change.

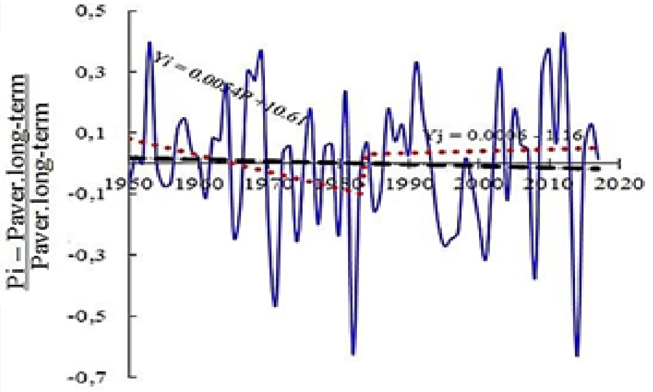


Figure 7. Ratio of difference between annual mean and annual long-term to annual long-term and trends of precipitation in Yavan before and after reservoir construction.

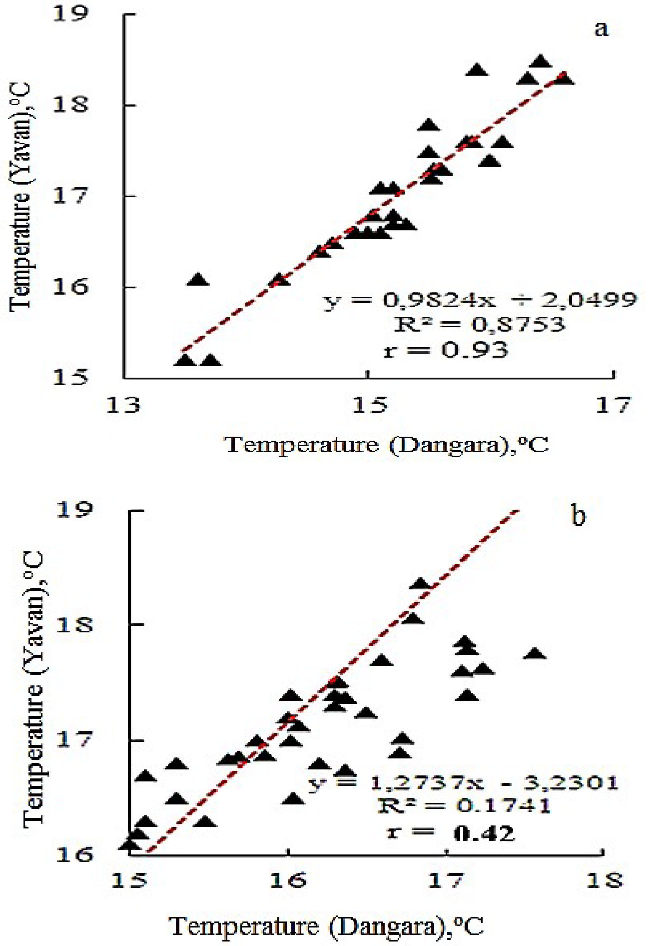


Figure 8. Correlation of mean annual long-term temperatures of Dangara and Yavan for the periods 1950 - 1979 (a) and 1980 - 2020 (b).

Mutual correlation of the Dangara and Yavan districts meteorological characteristics. Fig.8 shows the correlations between temperature and precipitation in Dangara and Yavan districts.Fig.8(a), which shows the correlation between the mean annual temperature values of Yavan and Dangara for the period 1950 -1980 (the period prior to the construction of the reservoir), shows their close relationship with a correlation coefficient of 0.93. Consequently, it can be expected that the occurrence of even small perturbations in the natural dynamics of temperatures in the areas under consideration should be reflected in the correlation dependence of the meteorological characteristics studied. This is exactly the pattern that is evident in the correlation between the temperatures of Yavan and Dangara for the period 1981 - 2020. As can be seen in Fig.8 (b), the temperature correlation coefficient drops to 0.77. This graph means that the temperature regime in one of the areas considered has been subjected to an external perturbation.

It is also important to assess the change in precipitation in areas adjacent to the reservoir in the presence of a suspected perturbation source. A comparison of the precipitation correlations shown in Fig. 9 shows that, as in the case of temperature, the precipitation of the Dangara and Javan areas is perturbed over the period 1981-2020, resulting in a decrease in the value of the precipitation correlation coefficient (Fig.9, b).

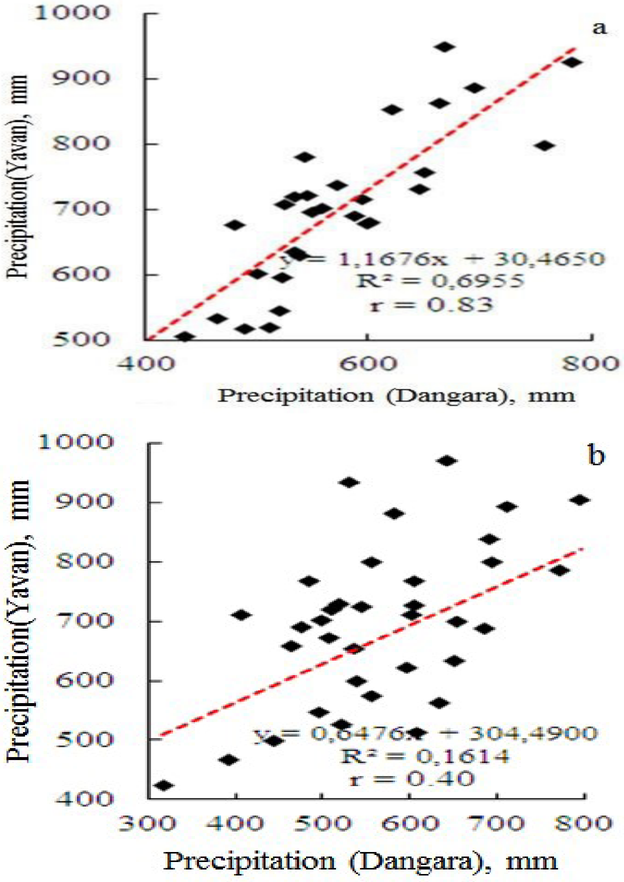


Figure 9. Correlation of mean annual precipitation in Dangara and Yavan for the periods 1950 - 1979 (a) and 1980 - 2020 (b).

To explain the correlations between the temperature of temperature of Dangara for the period 1981 - 2020 has Dangara and Javan districts for the period 1950 - 2020, increased by 1.2oC compared to the period 1950 - 1979. we refer to Fig.10, which shows the values of mean For Yavan district, on the other hand, the temperature annual temperatures in the study areas under difference between the two periods is negligible, being consideration. Fig.10 shows that the mean annual only 0.2oC.

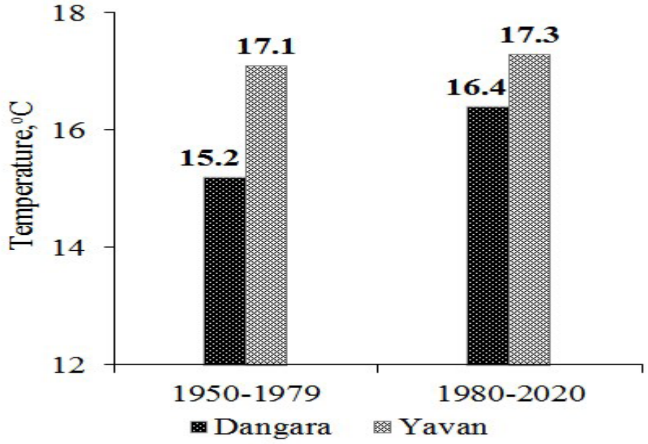


Figure 10. Annual long-term temperature of Dangara and Yavan districts for the periods 1950 – 1979 and 1980 – 2020.

Evapotranspiration dynamics in the riparian areas of the Nurek reservoir and assessment of drought potential. The arid and semi-arid climatic conditions of the Central Asian region are conducive to the occurrence of drought, and the frequency of this phenomenon has increased significantly with climate warming. Given the importance of demographic factors and food security issues in Central Asia, drought can have a significant negative impact on the socio-economic conditions of the countries in the region. To date, a whole class of indicators has been developed to assess drought, known as indices, which make it possible to determine the depth of drought depending on the meteorological conditions of the area Of the existing indices, the most widely used is the Standardised Precipitation Index (SPI), which is independent of geographical location, time and climate and requires only precipitation values for its calculation. When precipitation and moisture are adequate, the SPI is positive, and when precipitation is deficient, it is negative.

Under conditions of drought and climate change, failure to take surface temperature into account when determining drought can lead to unfortunate errors. Consequently, another index was needed to take full account of meteorological conditions in determining drought. Such an index to compensate for the shortcomings of the SPI is the Standardised Precipitation and Evapotranspiration Index (SPEI). This index is based on the use of the density distribution of the difference between precipitation and evapotranspiration [59].

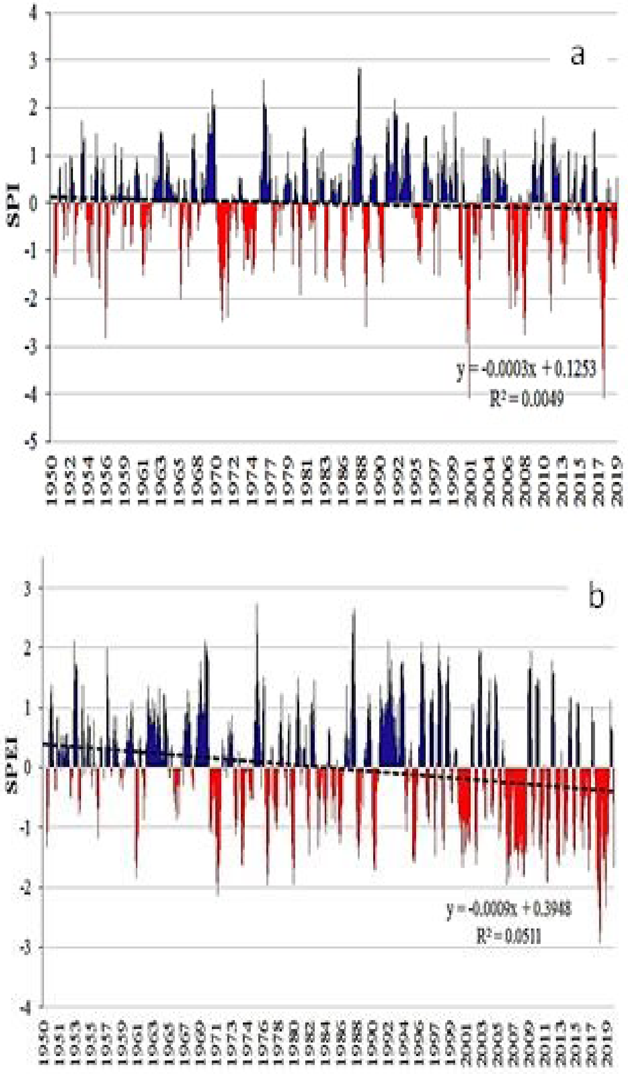


Figure 11. Standardized precipitation index (a) and the standardized precipitation and evapotranspiration index (b) from Dangara meteostation data for the period 1950 – 2019.

Fig.11 shows a decreasing trend in precipitation, with from the histograms in Fig.12, which show an increase the decreasing trend intensifying after 2000 which in the number of months with extreme and severe increases the probability of drought. This can be seen droughts.

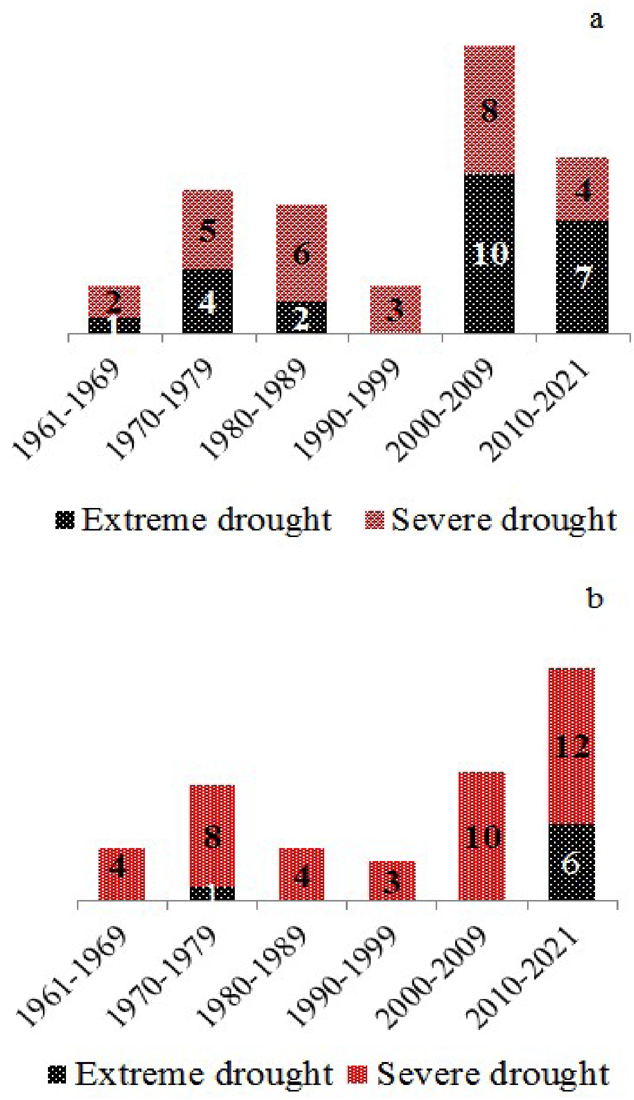
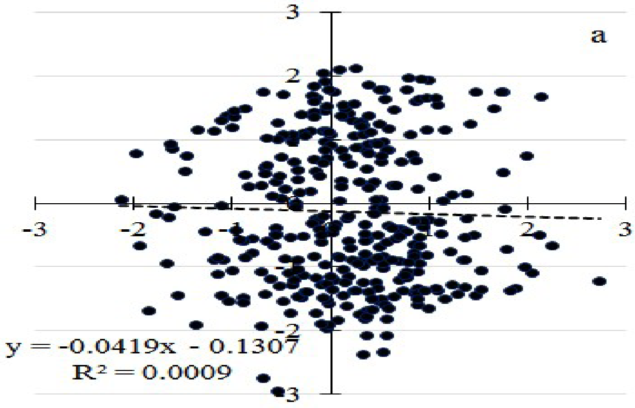


Figure 12. Number of months with drought SPI (a) SPEI (b) in Dangara district in each decade of the period 1961-2021.



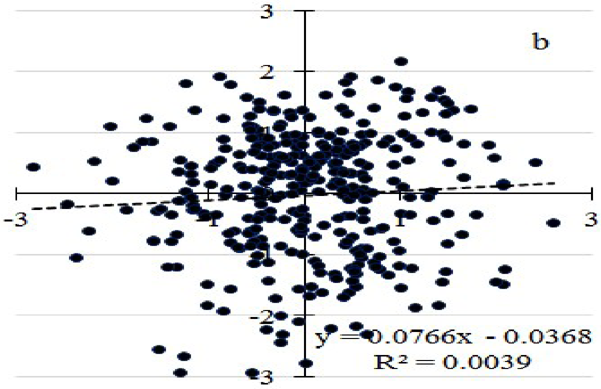


Figure 13. Correlation of SPEI and SPI in Dangara for periods before (1950-1979) (a) and after (1980-2020) (b) the construction of the Nurek reservoir.

The correlation between the SPI and SPEI index values in the years before and after the construction of the reservoir is quite different, with high correlation coefficients of 0.61 for the SPI and 0.57 for the SPEI (Fig. 14).

The results obtained suggest that the climatic conditions of Dangara district changed after the construction of the Nurek reservoir.

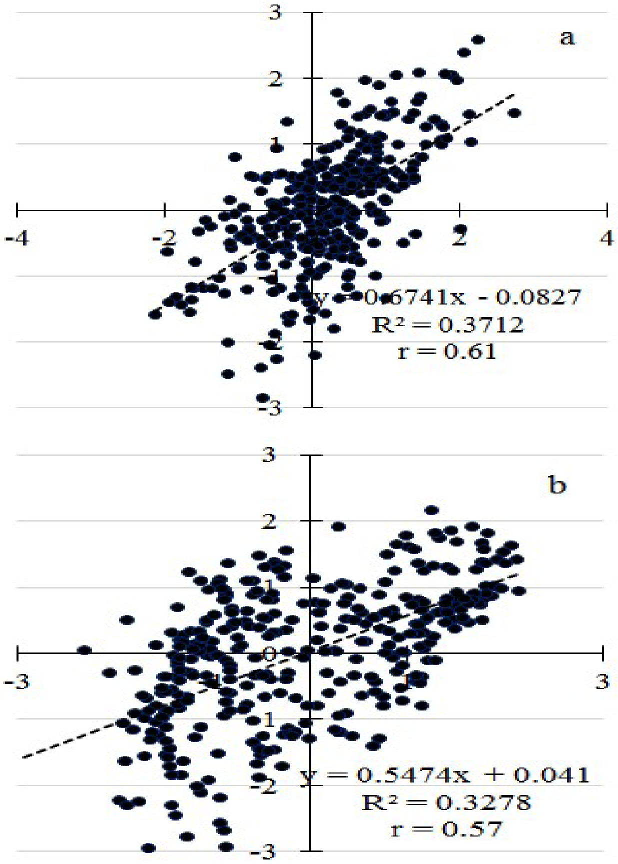


Figure 14. Correlation of SPI and SPEI in Dangara for the periods before (1950-1979) (a) and after (1980-2020) the

construction of the Nurek reservoir.

Fig.15 shows the dynamics of change in the drought increased significantly over the last decade. This is

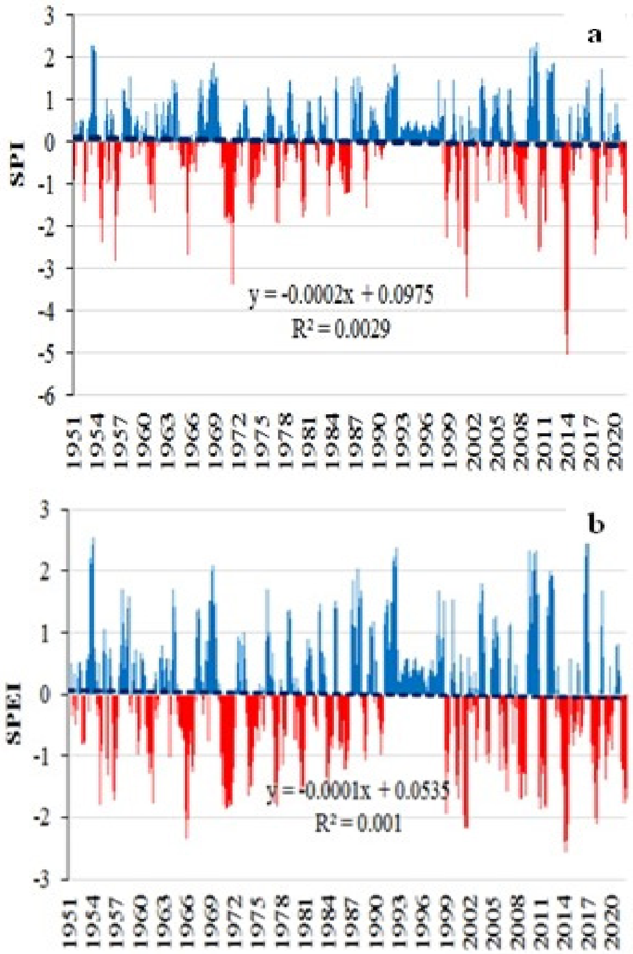
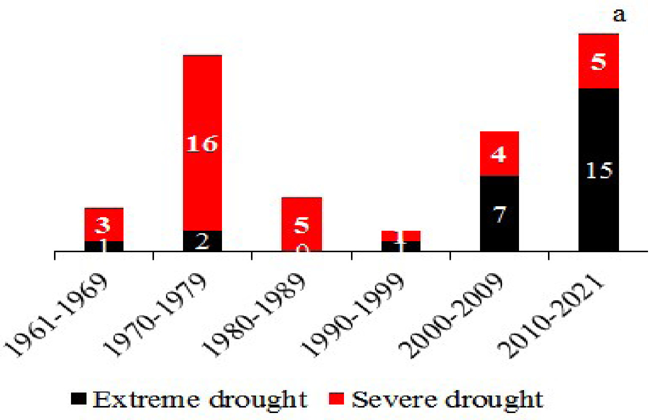


Figure 15. Standardized precipitation index (a) and the standardized precipitation and evapotranspiration index (b) values from Yavan meteostation data for the period 1950 -2019.



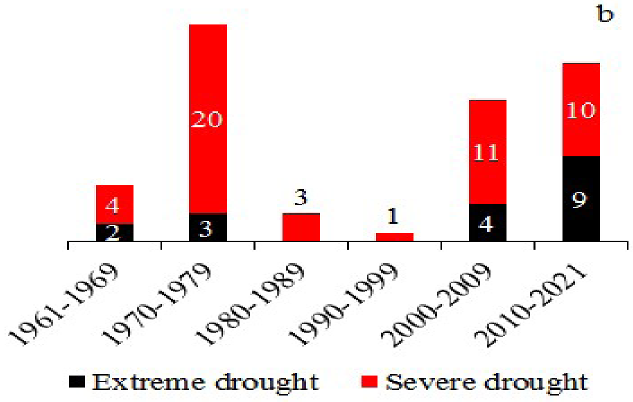


Figure 16. Number of months with extreme and severe drought in Yavan district for the period 1961- 2021 according to the SPI (a) and SPEI (b) indices.

To explain these results, we refer to Fig. 10 and Fig. 17, which show the temperature and precipitation values of Yavan district before and after the construction of the Nurek reservoir, respectively.

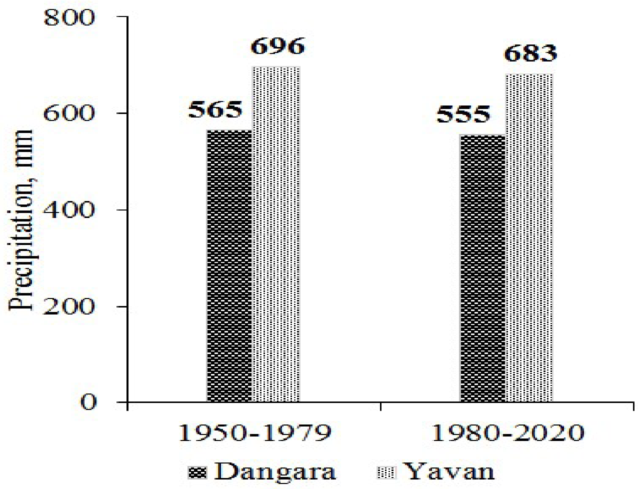


Figure 17. Mean annual precipitation from "Dangara" and "Yavan" meteostation before and after the construction of the Nurek reservoir.

Analysis of the data shown in Fig. 10 and Fig. 17 especially the decrease in rainfall contribute to the indicates that the difference in mean annual temperature and precipitation between the periods before (1950 - 1979) and after (1980 - 2020) the construction of the reservoir in Dangara district is 1.2°C and 10 mm, respectively and in Yavan district 0.2oC and 12.7 mm respectively. In other words, there has been an increase in temperature and a decrease in precipitation in the above districts. The increase in temperature and increase in the probability and frequency of drought. Fig.18 (a, b) shows the correlation dependence of the drought indices SPI and SPEI for the periods before and after the construction of the Nurek reservoir for the Yavan district. As can be seen from Fig.18, there is almost no correlation between the drought indices of the two periods, characterised by correlation coefficients of 0.20 and 0.19 for SPI and SPEI respectively.

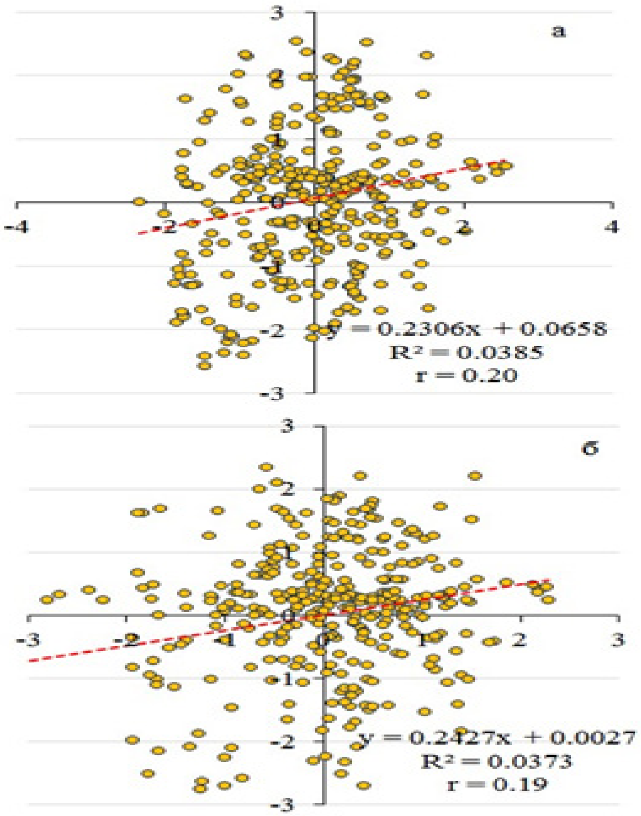
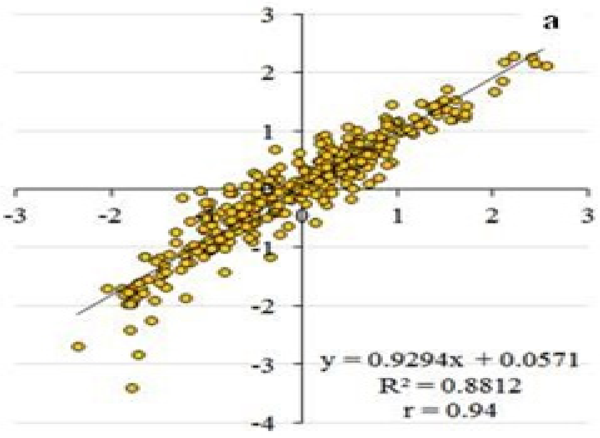


Figure 18. Correlation of SPEI and SPI in Yavan for periods before (1950-1979) (a) and after (1980-2020) (b) construction of the Nurek reservoir.

Mutual correlation of SPI and SPEI indexes in the years high correlation coefficients of 0.94 for SPI and 0.93 for before and after reservoir construction, characterised by SPEI (Fig.19).



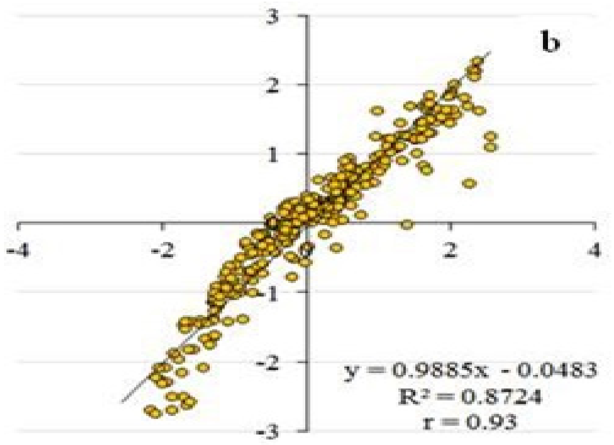


Figure 19. Correlation of SPI and SPEI in Yavan for the periods before (1950-1979) (a) and after (1980-2020) (b) the construction of the Nurek reservoir.

Conclusion

In the Central Asian region, the dominant sectors and main water users are hydropower and irrigation, which have opposite regimes of river flow regulation in water use. For hydropower generation, most of the river flow is needed in the winter season to generate electricity, while for irrigation, water is important during the growing season. The incompatibility of the geographical location of the formation and dispersion zones and the transboundary nature of the main rivers in the Central Asian region lead to the need to build reservoirs for the management and rational use of hydropower and irrigation potential. In addition, the transboundary nature of the main water arteries of the region requires solving the problem of water resources allocation through interstate agreements and treaties. The expansion of the irrigation potential of new lands, the strengthening of the environmentally friendly energy production and the depth of the multi-year regulation of the river flow will be achieved by the construction of a number of new hydraulic structures with reservoirs, which are a guarantee of sustainable development. The research results show that the radius of influence of the Nurek reservoir is limited. However, using correlation methods, it is shown that the coastal areas feel the influence of the reservoir. It was found that the most significant impact of the Nurek reservoir is in the Yavan region. It is also important to assess the changes in precipitation in the areas adjacent to the reservoir.

References

1. Reservoirs. History of reservoir construction [Online.] Available: / https://geo-site.ru/

2. Methodological guidelines for the assessment of the environmental impact of hydraulic works. RD 15334.2-02.409-2003. JSC "VNIIG" named after B.E. Vedeneev, St. Petersburg, 2003.

3. Kerimkul, A., Madibekov, A. (2021). Influence of temperature regime on climate change of Kapshagai reservoir. Vestnik of KazNU. Geographical series, 63(4), 36-44.

1. Konapala, G., Mishra, A. K., Wada, Y., & Mann, M. E. (2020). Climate change will affect global water availability through compounding changes in seasonal precipitation and evaporation. Nature communications, 11(1), 3044.
2. Zhao, G., & Gao, H. (2018). Automatic correction of contaminated images for assessment of reservoir surface area dynamics. Geophysical Research Letters, 45(12), 6092-6099.
3. Zhang, H., Gorelick, S. M., Zimba, P. V., & Zhang, X. (2017). A remote sensing method for estimating regional reservoir area and evaporative loss. Journal of Hydrology, 555, 213-227.
4. Zhao, G., & Gao, H. (2019). Estimating reservoir evaporation losses for the United States: Fusing remote sensing and modeling approaches. Remote Sensing of Environment, 226, 109-124.
5. Tian, W., Liu, X., Wang, K., Bai, P., & Liu, C. (2021). Estimation of reservoir evaporation losses for China. Journal of Hydrology, 596, 126142.
6. Bozorgi, A., Bozorg-Haddad, O., Sima, S., & Loáiciga, H. A. (2021). Comparison of methods for estimating loss from water storage by evaporation and impacts on reservoir management. Water and Environment Journal, 35(1), 218-228.
7. Mady, B., Lehmann, P., Gorelick, S. M., & Or, D. (2020). Distribution of small seasonal reservoirs in semi-arid regions and associated evaporative losses. Environmental Research Communications, 2(6), 061002.
8. Huang, C., Chen, Y., Zhang, S., & Wu, J. (2018). Detecting, extracting, and monitoring surface water from space using optical sensors: A review. Reviews of Geophysics, 56(2), 333-360.
9. Gao, H. (2015). Satellite remote sensing of large lakes and reservoirs: From elevation and area to storage. Wiley Interdisciplinary Reviews: Water, 2(2), 147-157.
10. Deng, Y., Jiang, W., Tang, Z., Ling, Z., & Wu, Z. (2019). Long-term changes of open-surface water bodies in the Yangtze River basin based on the Google Earth Engine cloud platform. Remote Sensing, 11(19), 2213.
11. Wang, Y., Ma, J., Xiao, X., Wang, X., Dai, S., & Zhao, B. (2019). Long-term dynamic of Poyang Lake surface water: A mapping work based on the Google Earth Engine cloud platform. Remote Sensing, 11(3), 313.
12. Xia, H., Zhao, J., Qin, Y., Yang, J., Cui, Y., Song, H., ... & Meng, Q. (2019). Changes in water surface area during 1989–2017 in the Huai River Basin using Landsat data and Google earth engine. Remote Sensing, 11(15), 1824.
13. Chen, J., Kang, T., Yang, S., Bu, J., Cao, K., & Gao, Y. (2020). Open-surface water bodies dynamics analysis in the Tarim River Basin (North-Western China), based on Google Earth Engine cloud platform. Water, 12(10), 2822.
14. Penman, H. L. (1948). Natural evaporation from open water, bare soil and grass. Proceedings of the Royal Society of London. Series A. Mathematical and Physical Sciences, 193(1032), 120-145.
15. Edinger, J. E., Duttweiler, D. W., & Geyer, J. C. (1968). The response of water temperatures to meteorological conditions. Water Resources Research, 4(5), 1137-1143.
16. De Bruin, H. A. R. (1982). Temperature and energy balance of a water reservoir determined from standard weather data of a land station. Journal of Hydrology, 59(3-4), 261-274.
17. Mohseni, O., & Stefan, H. G. (1999). Stream temperature/air temperature relationship: a physical interpretation. Journal of hydrology, 218(3-4), 128-141.
18. McJannet, D. L., Webster, I. T., & Cook, F. J. (2012). An area-dependent wind function for estimating open water evaporation using land-based meteorological data. Environmental modelling & software, 31, 76-83.
19. McMahon, T. A., Peel, M. C., Lowe, L., Srikanthan, R., & McVicar, T. R. (2013). Estimating actual, potential, reference crop and pan evaporation using standard meteorological data: a pragmatic synthesis. Hydrology and Earth System Sciences, 17(4), 1331-1363.
20. Zarfl, C., Lumsdon, A. E., Berlekamp, J., Tydecks, L., & Tockner, K. (2015). A global boom in hydropower dam construction. Aquatic Sciences, 77, 161-170.
21. Elagib, N. A., & Basheer, M. (2021). Would Africa's largest hydropower dam have profound environmental impacts?. Environmental Science and Pollution Research, 28(7), 8936-8944.
22. Seo, S. N., & Seo, S. N. (2021). Energy revolutions: A story of the three gorges dam in China. Climate Change and Economics: Engaging with Future Generations with Action Plans, 113-129.
23. Bayazıt, Y. (2021). The effect of hydroelectric power plants on the carbon emission: An example of Gokcekaya dam, Turkey. Renewable Energy, 170, 181-187.
24. O'Connor, F. M., Abraham, N. L., Dalvi, M., Folberth, G. A., Griffiths, P. T., Hardacre, C., ... & Zeng, G. (2021). Assessment of pre-industrial to present-day anthropogenic climate forcing in UKESM1. Atmospheric Chemistry and Physics, 21(2), 1211-1243.
25. 26. Skeie, R. B., Berntsen, T. K., Myhre, G., Tanaka, K., Kvalevåg, M. M., & Hoyle, C. R. (2011). Anthropogenic

radiative forcing time series from pre-industrial times until 2010. Atmospheric Chemistry and Physics, 11(22), 11827-11857.

26. 27. Kum, G. (2016). The influence of dams on surrounding climate: the case of Keban Dam. Gaziantep University Journal of Social Sciences, 15(1), 193-204.
27. Gyau-Boakye, P. (2001). Environmental impacts of the Akosombo dam and effects of climate change on the lake levels. Environment, Development and Sustainability, 3, 17-29.
28. Martins, J., Fraga, H., Fonseca, A., & Santos, J. A. (2021). Climate projections for precipitation and temperature indicators in the douro wine region: The importance of bias correction. Agronomy, 11(5), 990.
29. Fonseca, A. R., & Santos, J. A. (2018). High-resolution temperature datasets in Portugal from a geostatistical approach: Variability and extremes. Journal of Applied Meteorology and Climatology, 57(3), 627-644.
30. Fonseca, A. R., Santos, M., & Santos, J. A. (2018). Hydrological and flood hazard assessment using a coupled modelling approach for a mountainous catchment in Portugal. Stochastic environmental research and risk assessment, 32, 2165-2177.
31. 32. Fonseca, A. R., & Santos, J. A. (2019). A new very high-resolution climatological dataset in Portugal: Application to hydrological modeling in a mountainous watershed. Physics and Chemistry of the Earth, Parts A/B/C, 109, 2-8.
32. Fonseca, A. R., & Santos, J. A. (2019). Predicting hydrologic flows under climate change: The Tâmega Basin as an analog for the Mediterranean region. Science of the total environment, 668, 1013-1024.
33. Santos, M., Fonseca, A., Fragoso, M., & Santos, J. A. (2019). Recent and future changes of precipitation extremes in mainland Portugal. Theoretical and Applied Climatology, 137, 1305-1319.
34. Fonseca, A. R., A. Santos, J., Varandas, S. G., Monteiro, S. M., Martinho, J. L., Cortes, R. M., & Cabecinha, E. (2020). Current and future ecological status assessment: a new holistic approach for watershed management. Water, 12(10), 2839.
35. Fonseca, A., & Santos, J. A. (2021). The impact of a hydroelectric power plant on a regional climate in Portugal. Atmosphere, 12(11), 1400.
36. Vieira, J., Fonseca, A., Vilar, V. J., Boaventura, R. A., & Botelho, C. M. (2012). Water quality in Lis river, Portugal. Environmental monitoring and assessment, 184, 7125-7140.
37. Fluixá-Sanmartín, J., Escuder-Bueno, I., Morales-Torres, A., & Castillo-Rodríguez, J. T. (2021). Accounting for climate change uncertainty in long-term dam risk management. Journal of Water Resources Planning and Management, 147(4), 04021012.
38. Vieira, J., Fonseca, A., Vilar, V. J., Boaventura, R. A., & Botelho, C. M. (2013). Water quality modelling of Lis river, Portugal. Environmental Science and Pollution Research, 20, 508-524.
39. Fonseca, A., Botelho, C., Boaventura, R. A. R., & Vilar, V. J. P. (2015). Global warming effects on faecal coliform bacterium watershed impairments in Portugal. River Research and Applications, 31(10), 1344-1353.
40. Tata, L. R. R. (2021). Biodiversity impact assessment of two large dam projects in India under long term multi-scenarios simulation. Impact Assessment and Project Appraisal, 39(4), 335-347.
41. Kundu, S., Pal, S., Talukdar, S., & Mandal, I. (2021). Impact of wetland fragmentation due to damming on the linkages between water richness and ecosystem services. Environmental Science and Pollution Research, 28(36), 50266-50285.
42. Wilk-Woźniak, E., Krztoń, W., & Górnik, M. (2021). Synergistic impact of socio-economic and climatic changes on the ecosystem of a deep dam reservoir: Case study of the Dobczyce dam reservoir based on a 30-year monitoring study. Science of the Total Environment, 756, 144055.
43. Niyogi, D., Kishtawal, C., Tripathi, S., & Govindaraju, R. S. (2010). Observational evidence that agricultural intensification and land use change may be reducing the Indian summer monsoon rainfall. Water Resources Research, 46(3).
44. Takata, K., Saito, K., & Yasunari, T. (2009). Changes in the Asian monsoon climate during 1700–1850 induced by preindustrial cultivation. Proceedings of the National Academy of Sciences, 106(24), 9586-9589.
45. Degu, A. M., Hossain, F., Niyogi, D., Pielke Sr, R., Shepherd, J. M., Voisin, N., & Chronis, T. (2011). The influence of large dams on surrounding climate and precipitation patterns. Geophysical Research Letters, 38(4).
46. Miller, N. L., Jin, J., & Tsang, C. F. (2005). Local climate sensitivity of the Three Gorges Dam. Geophysical Research Letters, 32(16).
47. Correia, M. D. F., da Silva Dias, M. A. F., & da Silva Aragão, M. R. (2006). Soil occupation and atmospheric variations over Sobradinho Lake area. Part two: A regional modeling study. Meteorology and Atmospheric Physics, 94(1), 115-128.
48. Yilmaz, L. (2006). Meteorological climate change effect of the Ataturk Dam in Turkey at Eastern Anatolia. Materials and Geoenvironment, 53(4), 467.
49. Kellogg, C. H., & Zhou, X. (2014). Impact of the construction of a large dam on riparian vegetation cover at

different elevation zones as observed from remotely sensed data. International Journal of Applied Earth Observation and Geoinformation, 32, 19-34.

50. Aguiar, F. C., Fernandes, M. R., Martins, M. J., & Ferreira, M. T. (2019). Effects of a large irrigation reservoir on aquatic and riparian plants: A history of survival and loss. Water, 11(11), 2379.
51. Santos, R. M. B., Fernandes, L. S., Cortes, R. M. V., Varandas, S. G. P., Jesus, J. J. B., & Pacheco, F. A. L. (2017). Integrative assessment of river damming impacts on aquatic fauna in a Portuguese reservoir. Science of the Total Environment, 601, 1108-1118.
52. Santos, M. J., Pedroso, N. M., Ferreira, J. P., Matos, H. M., Sales-Luís, T., Pereira, Í., ... & Santos-Reis, M. (2008). Assessing dam implementation impact on threatened carnivores: the case of Alqueva in SE Portugal. Environmental Monitoring and Assessment, 142, 47-64.
53. World Meteorological Organization. Guide to Meteorological Instruments and Methods of Observation, Secretariat of the World Meteorological Organization: Geneva, Switzerland. 1983.
54. Klein Tank, A. M., Wijngaard, J. B., Können, G. P., Böhm, R., Demarée, G., Gocheva, A., ... & Petrovic, P. (2002). Daily dataset of 20th-century surface air temperature and precipitation series for the European Climate Assessment. International Journal of Climatology: A Journal of the Royal Meteorological Society, 22(12), 1441-1453.
55. Andrade, C., Fonseca, A., & Santos, J. A. (2021). Are land use options in viticulture and oliviculture in agreement with bioclimatic shifts in Portugal?. Land, 10(8), 869.
56. Pavlova, A.I. (2024). Assessment of meteorological drought on the basis of climatically standardized index of precipitation and evaporation. Agrarny Vestnik Urala, 24 (5), 605-616.