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NATIONAL RESEARCH UNIVERSITY "TASHKENT INSTITUTE OF IRRIGATION AND AGRICULTURAL MECHANIZATION ENGINEERS"

UMIDKHON UZBEKOV ULUGBEK UGLI

ASSESMENT OF CLIMATE CHANGE IMPACT ON HYDRAULIC AND HYDROLOGICAL REGIME OF RESERVOIRS

05.09.07-Hydaulics and engineering hydrology

DISSERTATION ABSTRACT OF THE DOCTOR OF PHILOSOPY (PhD) IN TECHNICAL SCIENCES

Tashkent-2025

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INTRODUCTION (Abstract of PhD thesis)

Relevance and necessity of the dissertation topic. Reservoirs represent one of the key elements in global water resource management. The application of modern technologies and technical solutions in regulating river flows through reservoirs and large-scale water intake infrastructure plays a vital role. In the context of global climate change, where the periodicity and intensity of precipitation have undergone significant alterations, there is a growing need to adopt advanced practices for managing the distribution of water flows from both hydraulic and hydrological perspectives. Accordingly, the utilization of reservoirs in managing water bodies must be aligned with the specific geographical and hydrological characteristics of each region.

Globally, rising temperatures, shifts in precipitation patterns, and the increasing frequency of droughts have led to a decline in reservoir storage levels. In response, extensive scientific research is being conducted to develop innovative, resource-efficient technologies and technical solutions aimed at ensuring the sustainable operation of reservoirs. Particular emphasis is being placed on the advancement and implementation of cutting-edge tools in reservoir water management such as SWAT (Soil and Water Assessment Tool), SCAD (Supervisory Control and Data Acquisition), and GAT (Geospatial Analysis Technologies) as well as on the scientific substantiation of their hydraulic and hydrological operational regimes.

In the Republic of Uzbekistan, comprehensive measures are being undertaken to address the implications of climate change. These include the construction of flood control reservoirs, the enhancement of the efficiency and longevity of hydraulic infrastructure, and the improvement of flow regulation and assessment methods in major hydraulic systems operating under irrigation conditions. The Concept for the Development of Water Management in the Republic of Uzbekistan for 2020–2030 outlines strategic objectives, notably the “ensuring of safe and reliable operation of water storage and flood control reservoirs and other water bodies.” To achieve these goals, tasks have been identified that include the analysis of river water consumption dynamics and their impact on the hydraulic and hydrological regimes of reservoirs, as well as the formulation of alternative operational strategies[1]. In this context, the development of theoretical foundations and practically applicable methodologies is of particular significance. This includes conducting in-depth analyses of changes in river discharge patterns, assessing their implications for reservoir performance, and proposing scientifically grounded and adaptable operating modes to ensure the long-term sustainability and resilience of water management systems.

[1] Decree of the President of the Republic of Uzbekistan No. PF-6024 dated July 10, 2020 “On the Concept of the Development of Water Management of the Republic of Uzbekistan for 2020-2030”

A series of presidential decrees and governmental resolutions underpin the strategic framework within which this dissertation is situated. These include Presidential Decree # PD-60 dated January 28, 2022, "On the Development Strategy of New Uzbekistan for 2022–2026"; Decree # PD-6024 dated July 10, 2020, "On Approval of the Concept of Water Management Development of the Republic of Uzbekistan for 2020–2030"; Resolution # PD-4486 dated October 9, 2019, "On Measures to Further Improve the Water Resources Management System"; and Resolution # PD-5005 dated February 24, 2021, "Strategy for the Development of Water Resources Management and the Irrigation Sector in the Republic of Uzbekistan for 2021–2023." This dissertation research is intended to contribute, to a certain extent, to the implementation of the objectives outlined in these policy documents. In particular, it aligns with the goals set forth in Cabinet of Ministers Resolution # 362 dated August 11, 2023, "On the Development and Effective Implementation of a National Action Plan on Climate Change and Natural Disaster Risk," as well as other relevant regulatory and legal frameworks supporting climate adaptation and water governance reforms in Uzbekistan.

Compliance of the research with the national priority directions for the advancement of science and technology of the Republic. This research was carried out within the framework of the V. Priority Direction of the Development of Science and Technology of the Republic "Agriculture, Biotechnology, Ecology and Environmental Protection".

The degree of scholarly investigation into the problem. Many studies have been conducted in our republic and several foreign countries to assess the impact of climate change on the hydraulic and hydrological regime of reservoirs. Studies on the study of the hydraulic and gyrological regimes of reservoirs and changes in them have been carried out by S. Aloui, S.L. Beharry, R.K. Jaiswal, X. Lui, T. Lui, M. Yasir, T. Duc Dang, X. Meng, C. Teutschbein, T. Thomas, W. Tian, J. Yao, A. Ashu, R. Allan, I. Bano, O. Barbosa, A. Bliss, F. Choukri, D. Frame, Y. Grusson, S. Hagesmann, C. Li, U. Mandal, D. Maraun, D. Molden, as well as scientists of our republic S.R. Ibatullin, F.K. Khikmatov, M.R. Bakiyev, I.R. Ikramova, A.M. Arifzhanov, A.T. Salohiddinov, F.A. Gapparov, I.A. Akhmedhojayeva, Sh. Rahmatullaev, S. Usmanov and a number of other scientists have conducted research and achieved certain positive results.

Extensive research on climate change forecasting, the assessment of its impacts on natural resources, and the development of adaptation strategies has been carried out by numerous prominent scholars at the international and national levels. Among the internationally recognized experts are J. Hansen, M. E. Mann, C. L. Quéré, V. Ramanathan, S. Seneviratne, K. Hayhoe, D. Chen, P. Zhai, A. Yatagai, and G. J. van Oldenborgh, whose work has significantly advanced global understanding of climate dynamics and response mechanisms. In parallel, researchers from the Republic of Uzbekistan, including B. Nishonov, P. Pulatov, A. Gafurov, M. Sarikulov, S. Abdullayeva, A. Hamidov, N. Khakimov, S. Turaeva, and others, have made important contributions to regional studies on climate change and its implications

for water resources, agriculture, and ecosystems. Based on their findings, a range of scientific recommendations have been developed to mitigate the adverse effects of climate change and support national efforts to strengthen resilience and adaptive

In the conducted scientific research, hydrological calculations were carried out on the impact of climate change and its impact on the amount of water resources, the hydrological regime of reservoirs. As a result, methods were developed to assess the changes in the amount of water in reservoirs over the years and months of their supply, to develop the operating regime of reservoirs, and to calculate the water balance. The use of modern methods in assessing the impact of climate change on the hydraulic and hydrological regimes of reservoirs, and the use of reliable assessment models, are waiting for a solution to the issues of sustainable management of water resources in future climate scenarios.

The relevance of the dissertation topic to the research plans of the higher educational institution where the dissertation was completed.

The dissertation research was carried out within the framework of the projects #3 of the Tashkent Institute of Irrigation and Agricultural Mechanization Engineers' Research and Development Plan "Development of scientific and practical foundations for rational management of water resources in the context of global climate change, their use based on water-saving technologies and improvement of the ecological and reclamation condition of irrigated lands" (2020-2023);

#3.1 "Development of scientific foundations for the assessment of hydraulic and hydrological processes in irrigation systems, hydraulic structures and reservoirs based on information technologies" (2020-2023);

#3.3 "Development of scientific foundations for the assessment of hydraulic and hydrological aspects of the effective use of water resources in irrigation systems, hydraulic structures and reservoirs" (2024-2026).

Research goal. The objective of the study is to evaluate the impact of climate change on the hydraulic and hydrological regimes of reservoirs.

Research Tasks:

Analytical analysis of scientific work conducted to assess the impact of climate change on the hydraulic and hydrological regime of reservoirs;

Bias correction and analysis of climate model data (Coupled Model Intercomparison Project 6 (CMIP6));

Assessment of the impact of climate change on the hydraulic and hydrological regime of reservoirs using the SWAT model;

Development of recommendations for assessing the impact of climate change on the reservoir.

Research area. Hisorak reservoir, Shahrisabz district, Kashkadarya province

The research subject Changes in precipitation patterns and intensity, rising air temperatures, snowmelt dynamics, seasonal and annual distribution of water flow, changes in the balance of water accumulation and release, reservoir filling and emptying (irrigation) regimes, and climate scenarios are factors that affect the

operational efficiency of reservoirs, the availability of water resources, and their distribution.

Research methods. The research used trend analysis of existing data, bias correction of climate model data, calibration and validation, GIS technologies, statistical analysis, and hydraulic and hydrological modeling (via the SWAT model).

The scientific novelty of the study:

software was developed to improve the accuracy and bias correction of climate model data using machine learning algorithms;

projected climate data from the CMIP6 global scenarios (SSP1-2.6 and SSP5-8.5) were statistically bias corrected and tailored to Oqsuv River Basin;

SWAT model parameters were optimized to enhance the simulation of reservoir hydraulic and hydrological regime dynamics under conditions of climate variability;

the operational regime of Hisorak reservoir was formulated using an enhanced SWAT model for varying hydrological periods.

Scientific and practical significance of the research results.

The scientific significance of the research results is that the accuracy of climate change analysis in reservoirs was increased by developing a software program for bias correction of climate model data in the Python programming language.

Also, taking into account climate variability, the SWAT model parameters necessary for assessing the impact of climate change on the hydraulic and hydrological regime of reservoirs were improved.

The practical significance of the research results is explained by the fact that modeling the impact of climate change on the hydraulic and hydrological regime of reservoirs will allow for more effective management of reservoirs by predicting future water consumption in reservoirs, changes in water levels in reservoirs, and periods of high and low water levels.

Implementation of research results. Based on the results of the scientific research on "Assessment of the impact of climate change on the hydraulic and hydrological regime of reservoirs":

climate change model data for the reservoir basin were analyzed and errors in them were corrected using the statistical method (bias correction) (Reference of the Ministry of Water Management of the Republic of Uzbekistan dated December 21, 2024 # 02/13-5019). As a result, the accuracy of the available climate model data for the reservoir basin and their analysis was increased.

model parameters were improved when predicting changes in the hydraulic and hydrological regimes of reservoirs (Reference of the Ministry of Water Management of the Republic of Uzbekistan dated December 21, 2024 # 02/13-5019). As a result, the accuracy of assessing the impact of climate change on the hydraulic and hydrological regime of reservoirs was increased.

the reservoir operating mode was developed based on the improved SWAT model for different water periods (Reference # 02/13-5019 of the Ministry of Water Resources of the Republic of Uzbekistan dated December 21, 2024). As a result, the

reservoir's operating efficiency was increased in the process of intensifying climate change.

Approbation of research results. The results of this research were discussed at 3 international and 2 republican scientific and practical conferences.

Publication of research results. 9 publications were published on dissertation works. 9 were published in scientific publications recommended for publication of the main scientific results of doctoral dissertations of the Higher Attestation Commission of the Republic of Uzbekistan, including 5 republican and 2 foreign journals and scientific conferences materials, and 2 authorship certificates were obtained.

Thesis structure and size. The dissertation consists of an introduction, four chapters, a conclusion, a list of references, and comprises a total of 93 pages.

MAIN CONTENT OF THE DISSERTATION

The introduction establishes the relevance and necessity of the dissertation topic, formulates the goals and objectives of the research, as well as the objects and subjects, indicates the correspondence of the research to the priority areas of development of science and technology of the Republic of Uzbekistan, describes the scientific novelty of the research and the practical results of the research. The theoretical and practical significance of the results obtained is revealed, information on the implementation of the research results, published works and the structure of the dissertation is provided.

The first chapter, entitled "**Analytical analysis of studies conducted to assess the impact of climate change on the hydraulic and hydrological regime of the reservoir**", is devoted to reviewing conducted research on how climate change alters the hydraulic and hydrological patterns of reservoirs and to synthesizing the modeling approaches used to assess those impacts. It first establishes why reservoirs matter and how climate-driven shifts in precipitation, evapotranspiration, snow/glacier dynamics and extremes reshape inflows, storage and operational risks, setting up the need for model-based analysis.

A core finding of the review is that SWAT is the dominant basin-scale tool in this literature: the chapter summarizes more than ten SWAT-based case studies across Iran (Zayandeh-Roud), China (Yangtze and Yalong), Thailand (Mun), India (Subarnarekha, Narmada), Morocco (Tleta), Japan (Sagami), Canada (Shellmouth), Portugal (Vigia/Monte Novo), Korea (Osan), the Caribbean (Navet), and others each calibrated/validated (often with SWAT-CUP/SUFI-2) and used to test climate and management scenarios. In parallel, the chapter shows that most studies couple SWAT with climate-scenario projections historically RCPs (e.g., 2.6/4.5/8.5) and increasingly CMIP6 SSPs (especially SSP1-2.6 vs SSP5-8.5) to drive hydrologic simulations and quantify future risks to flows, reliability and water quality.

The volume and breadth of SWAT+scenario studies summarized here demonstrate that a SWAT-based, scenario-driven methodology is appropriate and

strong for this thesis: it is widely used, transparent to calibrate/validate, compatible with CMIP6 SSP forcing, and directly links climate signals to reservoir-relevant metrics (inflows, storage, reliability, sediments), which aligns with the thesis objective to evaluate and optimize reservoir regimes under future climate.

The second chapter, entitled "**Bias correction and analysis of climate model data (Coupled Model Intercomparison Project 6 (CMIP6)) in water volume estimation**", in which the errors in the climate model data were corrected in the study area and the analysis of the climate model and Uzhydromet data was carried out. The average temperature from 1989 to 2023 shows significant fluctuations from year to year, with some years showing a sharp decrease or increase. However, the general trend, as shown by the upward-sloping red line, shows a gradual increase in the average temperature over time.

The slope of the trend line indicates an average annual increase in temperature of approximately 0.041 ° C per year during the study period. The blue line shows significant year-to-year variability in precipitation, with peaks in some years (e.g., above 1,200 mm) and sharp declines in others (e.g., below 600 mm). Despite this variability, the red trend shows a slight downward trend in annual precipitation over the observed period. The slope of the trend line (-1.6216) indicates an average annual decrease of 1.62 mm.

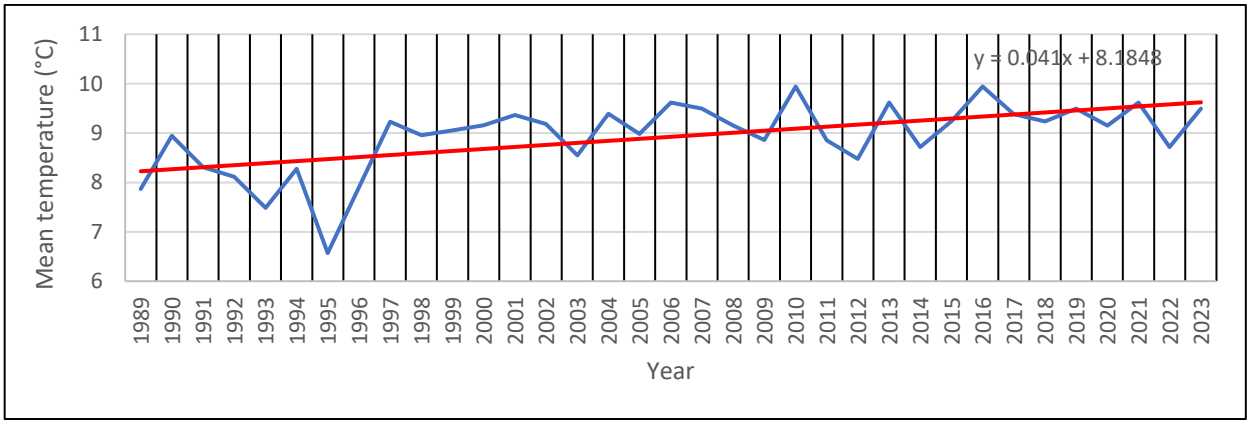

Figure 1. **Average annual temperature trend from 1989 to 2023 (Uzhydromet)**

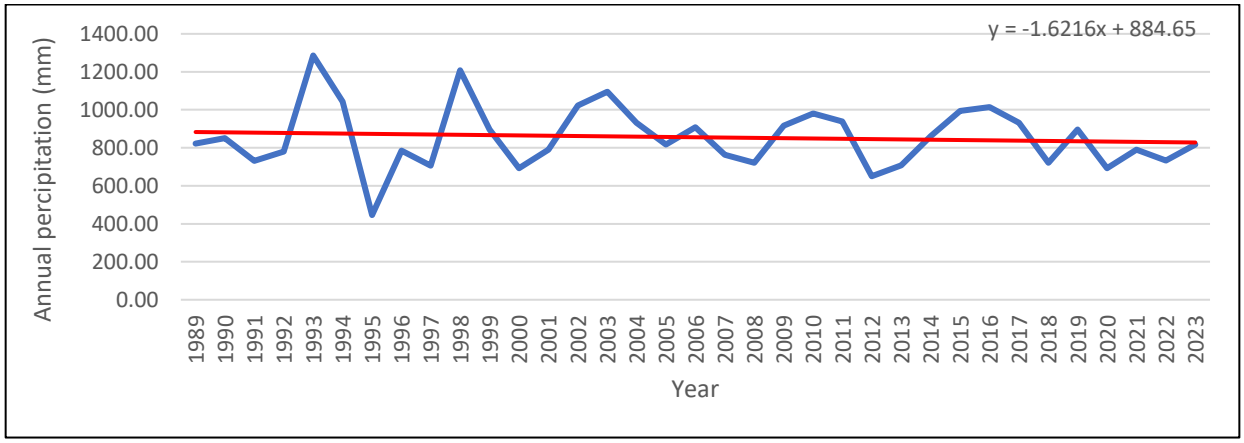

Figure 2. Average annual precipitation trend from 1989 to 2023 (Uzhydromet)

For temperature data, the mean bias before bias correction is reported as 0.92 °C, which reduces effectively to 0.00 °C after correction. This indicates that the bias correction process eliminates systematic deviations in the modeled temperature. The RMSE, which measures the overall error magnitude, decreases from 2.24 °C before correction to 2.04 °C after correction, reflecting an improvement in the accuracy of the modeled data.

The correlation coefficient (R), which reflects the strength of the linear relationship between modeled and observed temperatures, remains constant at 0.87 before and after correction. For precipitation data, the mean bias before correction is reported as 4.62 mm, which is reduced to 0.00 mm after correction, demonstrating the elimination of systematic over- or under-prediction in the precipitation data.

The upper right panel shows the temperature data for the SSP5-8.5 scenario, which represents a high-emission future. For temperature data, the mean bias before correction is reported as 1.87 °C, which is reduced to 0.00 °C after correction, indicating the elimination of systematic deviations. The root means square error (RMSE), which captures the overall magnitude of errors, decreases substantially from 3.07 °C before correction to 1.30 °C after correction.

For precipitation data (Figure 3), the mean bias before correction is reported as 4.65 mm, which is reduced to 0.00 mm after correction, signifying those systematic errors in precipitation magnitude are effectively removed. In summary, the analysis of both figures illustrates the robustness of the bias correction process in reducing systematic biases and overall error magnitudes in temperature and precipitation data under SSP5-8.5.

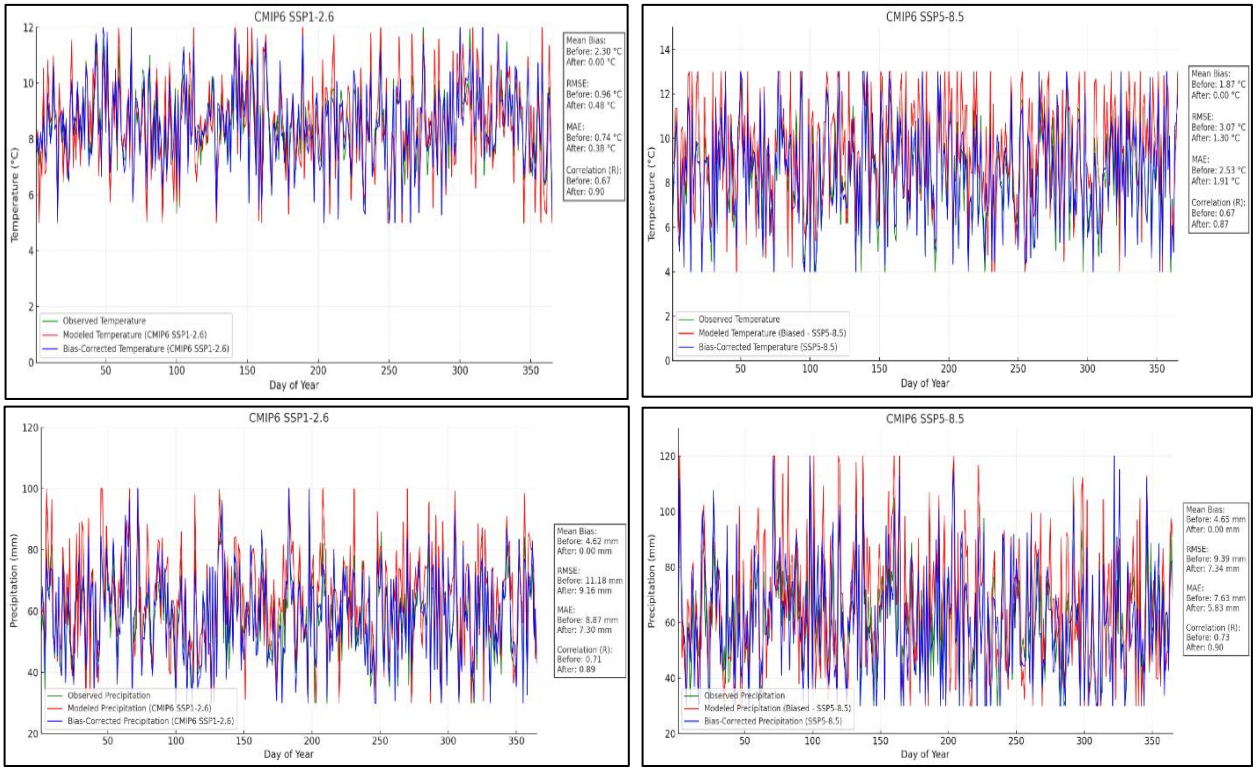

Figure 3. Temperature and precipitation data are corrected for two different CMIP6 climate scenarios: SSP1-2.6 (top left and bottom left) and SSP5-8.5 (top right and bottom right)

Over the next 30 years, temperatures are projected to increase by 1.8 °C. This rate is projected to be 0.06 °C per year. Over the next 30 years, precipitation in the Hisorak reservoir basin is projected to decrease by 176.6 mm, with an average annual decrease of 6.1 mm (Figure 4).

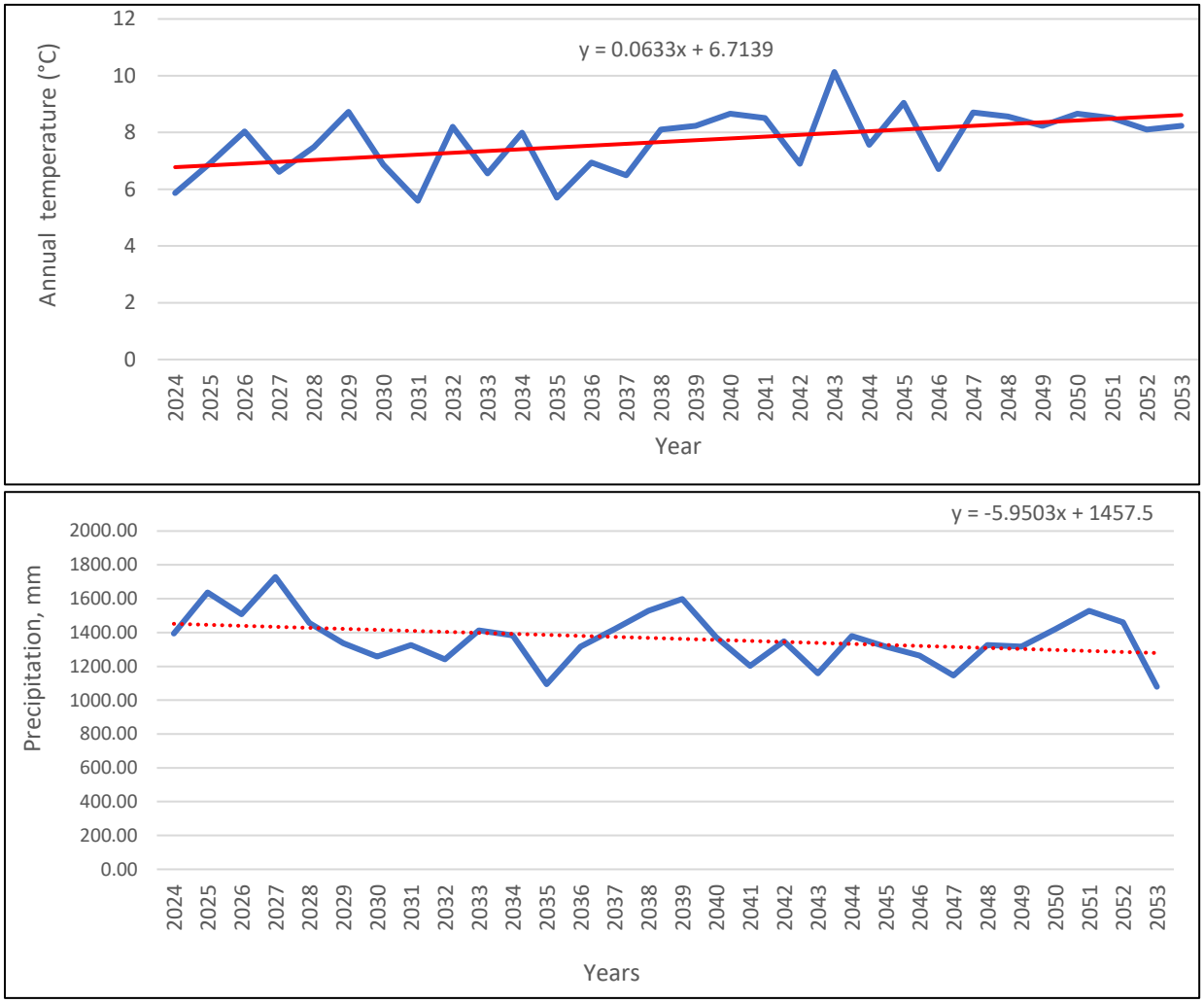

Figure 4. CMIP6 SSP1-2.6 scenario: temperature and precipitation

In the third chapter of the dissertation, entitled "**Assessment of the impact of climate change on the hydraulic and hydrological regime of the reservoir in the river basin using the SWAT model**", the impact of climate change on the hydraulic and hydrological regime of the reservoir was assessed using the SWAT model. During the study, various statistical indicators were used and analyzed to increase the accuracy and reliability of the SWAT model research results. The hydrological cycle as simulated by SWAT is based on the water balance equation:

$$SW_t = SW_0 + \sum_{i=1}^{t}\left(R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}\right) \quad (1)$$

Where: SWt is the final water content of the soil, SW0 is the water content in the early stage of the soil, t is time in days, Rday is the daily precipitation, Qsurf is the daily surface runoff, Ea is the daily evapotranspiration (ET), Wseep is the daily percolation, Qgw is the daily return flow, all units are in mm.

Furthermore, there are few statistical indicators, including NS (Nash–Sutcliffe efficiency), coefficient of determination (R^2), p-factor and r-factor, which evaluate

the quality of model output and model performance itself. Nash–Sutcliffe efficiency is essential in SWAT calibration because it gives a direct, single-number gauge of how well the simulated hydrograph follows the observed record.

$$\mathrm{NS} = 1 - \left[\frac{\sum_{i=1}^{n}\left(Q_{\mathrm{obs}}(i) - Q_{\mathrm{sim}}(i)\right)^2}{\sum_{i=1}^{n}(Q_{\mathrm{obs}}(i) - \bar{Q}_{\mathrm{obs}})^2}\right] \quad (2)$$

The coefficient of determination, R^2, is used in SWAT modeling to measure how well the simulated streamflow matches the observed values in terms of overall pattern and strength of relationship. It reflects the proportion of variance in the observed data that can be explained by the model outputs.

$$R^2 = \frac{\left[\sum_{i=1}^{n}(Q_{\mathrm{obs}}(i) - \bar{Q}_{\mathrm{obs}})(Q_{\mathrm{sim}}(i) - \bar{Q}_{\mathrm{sim}})\right]^2}{\sum_{i=1}^{n}(Q_{\mathrm{obs}}(i) - \bar{Q}_{\mathrm{obs}})^2 \ \sum_{i=1}^{n}(Q_{\mathrm{sim}}(i) - \bar{Q}_{\mathrm{sim}})^2} \quad 3)$$

Another indicator is the p-factor is used in SWAT modeling to evaluate how well the model's uncertainty range captures the observed data. It shows the proportion of measured streamflow values that fall within the 95% prediction uncertainty band generated during calibration.

$$\mathrm{p-factor} = \frac{\sum_{i=1}^{N} I(O_t \in [L_t,\ U_t])}{N} \quad (4)$$

The r-factor is used in SWAT modeling to assess the width of the 95% prediction uncertainty band relative to the variability of the observed data. Specifically, it represents the average thickness of this band divided by the standard deviation of the observed streamflow.

$$\mathrm{r-factor} = \frac{\frac{1}{n}\sum_{i=1}^{n}[\mathrm{U}_{95}(t) - \mathrm{L}_{95}(t)]}{\sigma_{\mathrm{obs}}} \quad (5)$$

In the left panel, water consumption data are plotted for the years from 1986 to 2000, measured in cubic meters per second (m^3/s). The green line represents the observed data, and the red line represents the SWAT model simulation. The two lines are closely related to each other throughout the entire period, indicating a strong agreement between the observed and modeled data. Both datasets show significant interannual variability, with flow peaking in some years (e.g., around 1987 and 1996) and decreasing in others (e.g., 1998 and 2000). This suggests that the SWAT model effectively captures temporal trends in river flow.

The scatter plot in the right panel compares observed discharge (x-axis) with simulated flow (y-axis). The red line represents a linear regression line with the equation y=0.8061x+58.04. Accordingly, an R^2 value of 0.86 indicates a strong positive correlation between the observed and simulated data. The 95% confidence interval (solid green lines) and the 95% prediction interval (dashed green lines) show the range of variability around the regression line. The data points are within the confidence and prediction intervals, further confirming the accuracy of the model (Figure 5). According to the results, in the SSP1-2.6. scenario, it decreased by 17.7%, while in the SSP5-8.5 scenario, this indicator returned to 28.5% (Figure 6,7).

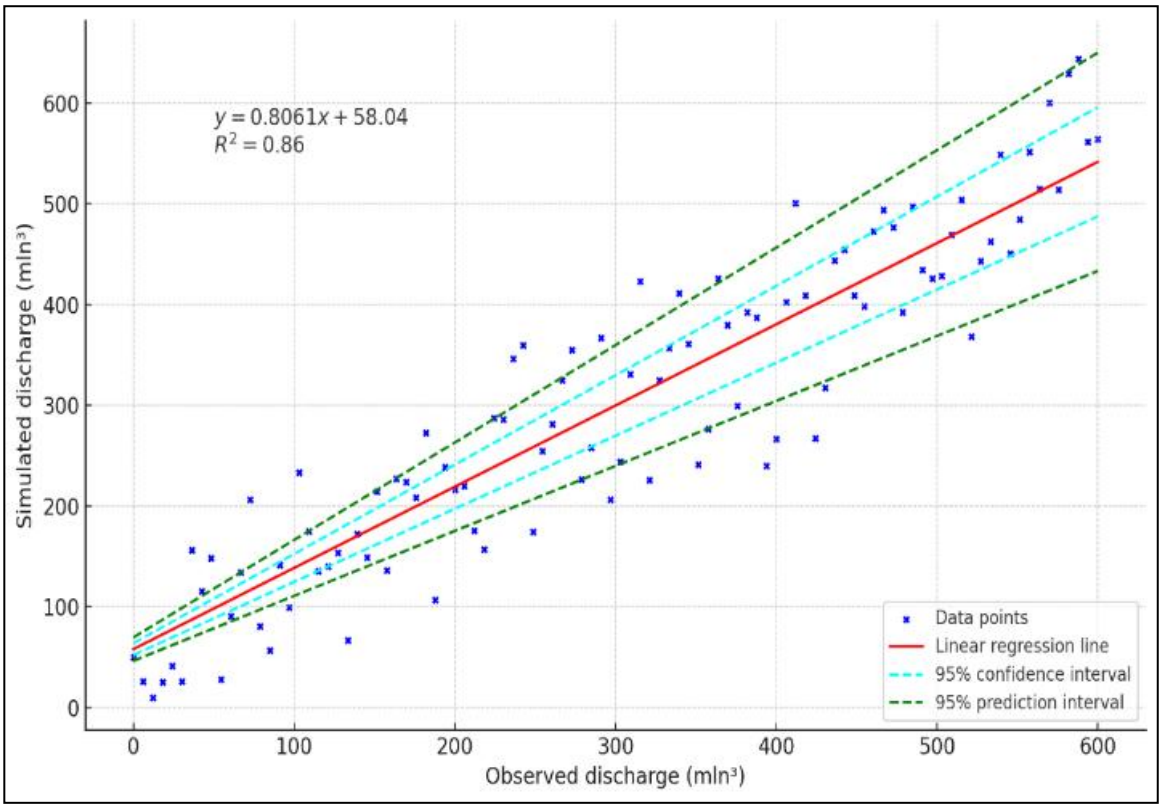

Figure 5. Analysis of Uzhydromet and SWAT model data

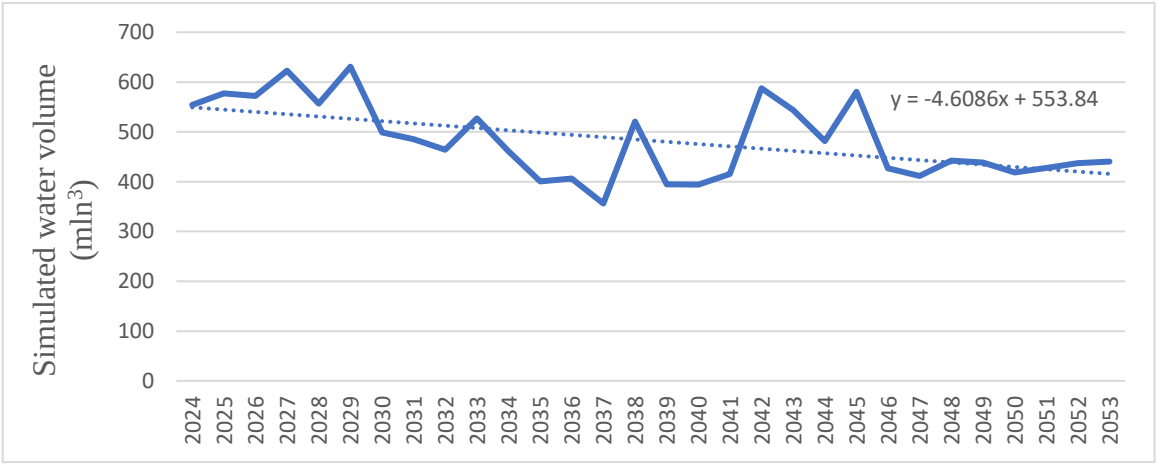

Figure 6. Water volume change for SSP1-2.6

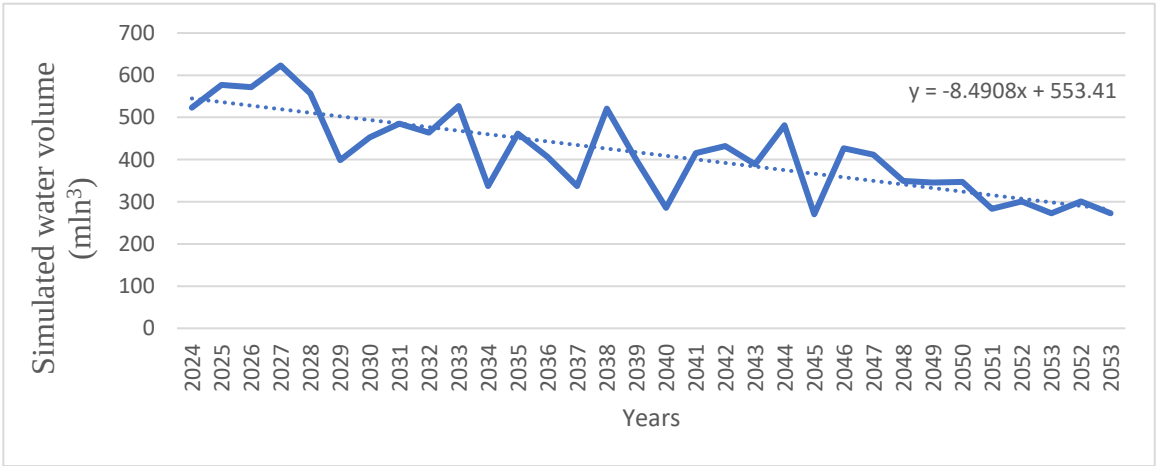

Figure 7. Water volume change for SSP5-8.5

The figure presents projected water level changes in the Hisorak Reservoir under two climate scenarios, SSP1-2.6 (low emissions) and SSP5-8.5 (high emissions), using SWAT model simulations. Under SSP1-2.6, water levels remain higher and more stable year-round (1100-1120 m), peaking in July with minimal seasonal fluctuation indicating adequate precipitation and runoff. In contrast, SSP5-8.5 shows lower levels overall (1060-1090 m), a sharp drop in late summer, and greater variability, likely due to increased evaporation, reduced snowmelt, and altered inflow. This suggests a heightened risk of water shortages under SSP5-8.5, particularly in late summer and autumn. The results underscore the importance of climate-resilient water management strategies to mitigate future risks (Figure 8).

The figure shows seasonal variations in water levels and intake at the Hisorak Reservoir under SSP1-2.6 and SSP5-8.5 climate scenarios, compared with actual and recommended intake levels. In spring, water intake increases steadily as irrigation demand rises, while reservoir levels remain stable and sufficient under both scenarios. By early summer, water levels peak, and intake reaches its maximum in June. However, intake drops sharply by August, falling to around 1045 meters below both recommended and projected levels indicating significant depletion likely due to overuse, reduced inflow, and high evaporation under SSP5-8.5. In autumn, intake begins to recover as demand declines and water levels gradually rise. During winter, intake remains low, allowing reservoir levels to stabilize before the next cycle. Notably, the recommended intake line stays consistently below SSP5-8.5 water levels throughout the year, suggesting it represents an optimized and more sustainable withdrawal strategy. Adopting this intake regime could help prevent critical shortages, particularly in late summer, and serves as a practical solution for ensuring water security under both current and future climate scenarios (Figure 9).

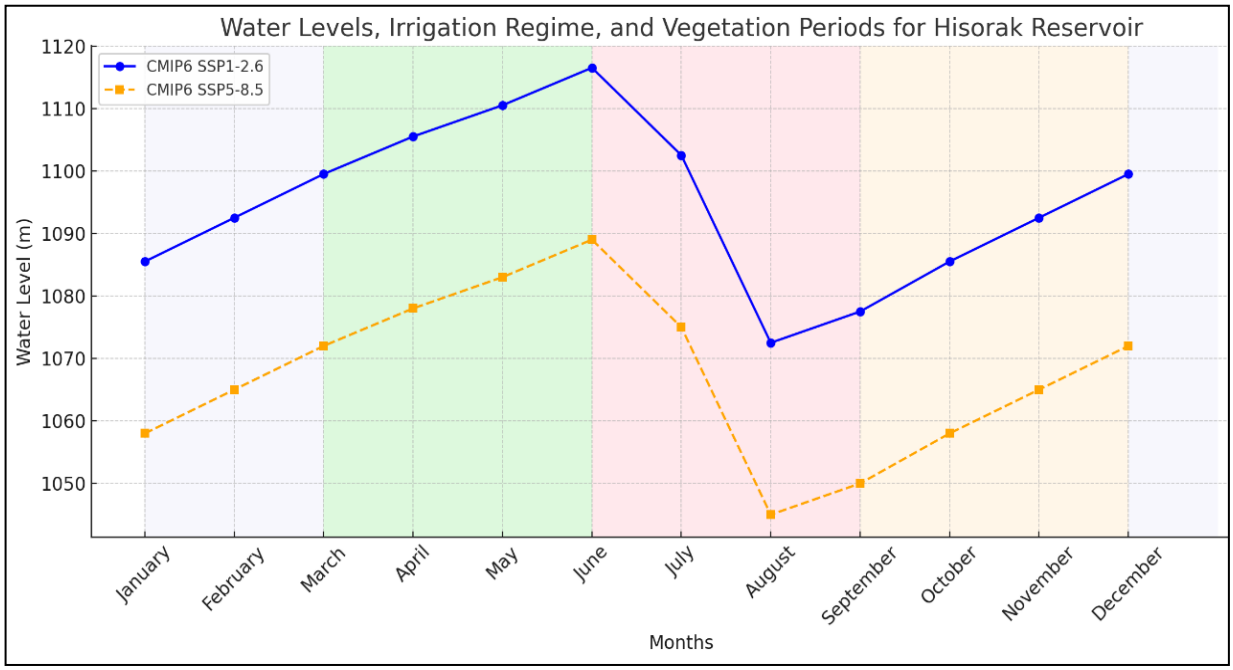

Figure 8. Water level change in Hisorak reservoir for CMIP6 SSP1-2.6 and CMIP6 SSP5-8.5

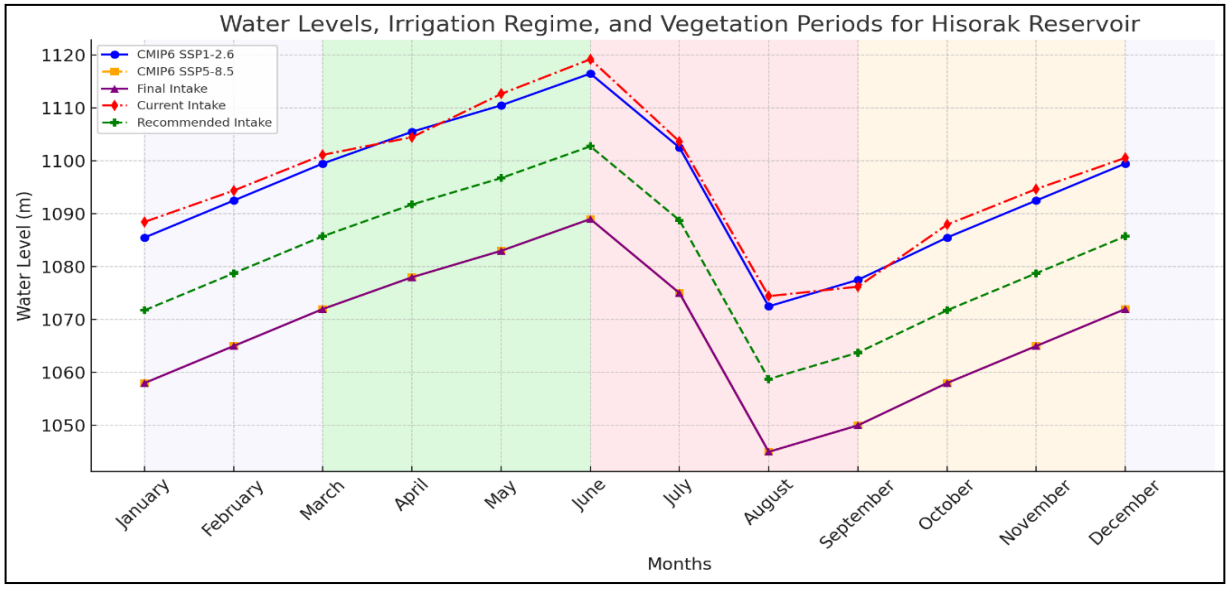

Figure 9. Irrigation regime for vegetation periods for Hisorak reservoir

The fourth chapter, entitled "**Development of recommendations for assessing the impact of climate change on the reservoir**", highlights the sustainable management challenges and opportunities of the Hisorak Reservoir under conditions of climate variability and long-term climate change. By applying the SWAT model with bias-corrected CMIP6 projections (SSP1-2.6 and SSP5-8.5), the research establishes clear evidence of declining annual runoff, seasonal shifts in reservoir levels, and heightened risks of extreme hydrological events. The simulations indicate a potential reduction in water availability of up to 28.5% under high-emission scenarios, with noticeable seasonal fluctuations, such as declining summer levels below 1060 m in severe cases.

The findings underline the necessity of adaptive and data-driven strategies, including real-time hydrological monitoring, early warning systems, and infrastructure upgrades to reduce evaporation and sediment losses. Special attention is placed on agricultural water use, with recommendations for improving irrigation efficiency, promoting drought-tolerant crops, and aligning planting schedules with new hydrological realities. The chapter also emphasizes flexible reservoir operation protocols and contingency planning for floods and droughts.

CONCLUSIONS

Based on the conducted research on the Hisorak Reservoir within the framework of this thesis, the following conclusions have been drawn:

1. The Hisorak Reservoir has experienced significant changes in its hydrological regime due to climate change. Reduced precipitation, rising temperatures, and altered flow patterns have resulted in a steady decline in water inflows between 1990 and 2020.

2. The application of bias correction to CMIP6 scenarios (SSP1-2.6 and SSP5-8.5) has substantially improved the reliability of climate projections. In the high-emission pathway (SSP5-8.5), bias correction was particularly effective, reducing

RMSE and MAE, while increasing correlation from 0.67 to 0.87, thereby enhancing both accuracy and temporal coherence of climate inputs.

3. Model simulations project that water availability will decline by approximately 28.5% under SSP5-8.5 and by 17.7% under SSP1-2.6 during 2024–2053. These reductions suggest significant constraints on future water resources, intensifying competition among agricultural, industrial, and domestic users.

4. Seasonal fluctuations in reservoir levels are expected to intensify under SSP5-8.5, with summer peaks followed by sharp declines that could drop below 1060 m in late August–September. Under SSP1-2.6, fluctuations remain less severe, stabilizing near 1070 m in mid-summer.

5. The study emphasizes that moderating peak irrigation demand by 10–15% in June–July can help maintain critical reservoir levels (e.g., above 1065–1070 m). This measure ensures stability of water supply throughout late summer and reduces the risk of severe shortages.

6. Projections under SSP5-8.5 highlight growing risks of prolonged droughts and severe flooding. Strengthened hydrological and meteorological monitoring systems are essential for improved flood forecasting, enabling pre-emptive and controlled reservoir releases to mitigate flooding risks.

“TOSHKENT IRRIGATSIYA VA QISHLOQ XO‘JALIGINI MEHANIZATSIYALASH MUHANDISLARI INSTITUTI” MILLIY TADQIQOT UNIVERSITETI HUZURIDAGI ILMIY DARAJALAR BERUVCHI DSC. 03/30.12.2019. T.10.2. RAQAMLI ILMIY KENGASH

“TOSHKENT IRRIGATSIYA VA QISHLOQ XO‘JALIGINI MEHANIZATSIYALASH MUHANDISLARI INSTITUTI” MILLIY TADQIQOT UNIVERSITETI

O‘ZBEKOV UMIDXON ULUG‘BEK O‘G‘LI

IQLIM O‘ZGARISHINI SUV OMBORLARNING GIDRAVLIK VA GIDROLOGIK REJIMIGA TA’SIRINI BAHOLASH

05.09.07-Gidravlika va muhandislik gidrologiyasi

TEXNIKA FANLARI BO‘YICHA FALSAFA DOKTORI (PhD) DESSERTATSIYASI AVTOREFERATI

Toshkent-2025

Texnika fanlari bo‘yicha falsafa doktori (PhD) dissertatsiyasi mavzusi O‘zbekiston Respublikasining Oliy ta’lim, fan va innovatsiyalar vazirligi huzuridagi Oliy attestatsiya kommiyasida B2025.2.PhD/T148. raqam bilan ro‘yxatga olingan.

“Toshkent irrigatsiya va qishloq xo‘jaligini mehanizatsiyalash muhandislari instituti” milliy tadqiqot universitetida bajarilgan.

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Dissertatsiya mavzusining dolzarbligi va zaruriyati. Jahonda suv resurslarini boshqarishda asosiy bug'inlardan biri suv omborlar bo'lib, daryolar oqimini suv omborlari va yirik suv olish inshootlari yordamida boshqarishda zamonaviy texnologiyalar va texnik vositalarini qo'llash yetakchi o'rinlardan birini egallamoqda. Dunyoda suv omborlarni barpo etishda global iqlim o'zgarishi natijasida yog'inlarning davriyligi o'zgarganligi, buning natijasida suv oqimlarining taqsimotini gidravlik va gidrologik nuqtai nazardan boshqarish amaliyotini joriy etishni taqozo etadi. Shu jihatdan iqlim o'zgarishi sharoitida suv omborlarni boshqarishda hududning geografik va gidrologik sharoitlarini hisobga olgan holda foydalanish muhim ahamiyatga ega hisoblanadi.

Jahonda haroratning oshishi, yog'ingarchilik taqsimotining o'zgarishi va qurg'oqchilik holatlarining tez-tez takrorlanishi natijasida suv omborlarning to'lish darajasi pasayishi natijasida ekspluatatsion rejimini barqaror olib boorish uchun zamonaviy resurstejamkor texnologiyalar va texnik vositalarining yangi ilmiy-texnikaviy yechimlarini ishlab chiqishga yo'naltirilgan ilmiy-tadqiqot ishlari olib borilmoqda. Bu borada, suv omborlarda suvni boshqarishda innovatsion texnologiyalar ya'ni SWAT, SCAD va GAT texnologiyalaridan keng foydalanishni amalga oshiradigan samarali texnologiyalarni ishlab chiqish hamda uning gidravlik va gidrologik ish rejimlarini asoslashga alohida e'tibor berilmoqda.

Respublikamizda iqlim o'zgarishini inobatga olib sel omborlarini barpo etish, gidrotexnik inshootlar samaradorligini va xizmat muddatlarini oshirish hamda ularning ishonchli ekspluatasiyasini ta'minlash, iqlim o'zgarishni inobatga olib irrigatsion rejimda ishlayotgan yirik gidrotexnik inshootlarda oqimni boshqarish va baholash usullarini takomillashtirishga yuzasidan keng qamrovli chora-tadbirlar amalga oshirilib, muayyan natijalarga erishilmoqda. O'zbekiston Respublikasi Suv xo'jaligining 2020-2030 yillarda rivojlantirish konsepsiyasida "suv va sel-suv omborlari va boshqa suv obe'ktlarini xavfsiz hamda ishonchli ishlashini ta'minlash" vazifalari belgilangan. Mazkur vazifalarni amalga oshirish, jumladan daryolardagi suv sarflari o'zgarishini tahlili va uning suv omborlarining gidravlik va gidrologik rejimiga ta'sirini baholash hamda muqobil ishlash rejimini ishlab chiqish bo'yicha muhim vazifalar belgilab berilgan[2]. Ushbu vazifalarini amalga oshirishda, jumladan, daryolardagi suv sarflari o'zgarishini tahlili va uning suv omborlarining gidravlik va gidrologik rejimiga ta'sirini baholash hamda muqobil ishlash rejimini ishlab chiqishga qaratilgan ilmiy va amaliy ahamiyatga ega bo'lgan nazariy asoslari hamda usullarini ishlab muhim ahamiyat kasb etmoqda.

O'zbekiston Respublikasi Prezidentining 2022 yil 28 yanvardagi PF-60-son «2022-2026 yillarga mo'ljallangan Yangi O'zbekistonning taraqqiyot strategiyasi to'g'risida»gi, 2020 yil 10 iyuldagi PF-6024-son "O'zbekiston Respublikasi Suv xo'jaligini rivojlantirishning 2020-2030 yillarga mo'ljallangan kontseptsiyasini tasdiqlash to'g'risida"gi Farmonlari, 2019 yil 9 oktyabrdagi PQ-4486 sonli "Suv resurslarini boshqarish tizimini yanada takomillashtirish bo'yicha chora-tadbirlari

[2] O'zbekiston Respublikasi Prezidentining 2020-yil 10-iyuldagi PF-6024-son O'zbekiston Respublikasi suv xo'jaligini rivojlantirishning 2020 - 2030-yillarga mo'ljallangan konsepsiyasi to'g'risidagi farmoni

to‘g‘risida”gi, 2021 yil 24 fevraldagi PQ-5005-sonli “O‘zbekiston Respublikasida suv resurslarini boshqarish va irrigatsiya sektorini rivojlantirishning 2021-2023 yillarga mo‘ljallangan strategiyasi” to‘g‘risidagi qarorlari, Vazirlar Mahkamasining 2023-yil 11-avgustdagi 362-sonli “Iqlim o‘zgarishi va tabiiy ofatlar xavfiga nisbatan milliy harakatlar rejasini ishlab chiqish hamda samarali amalga oshirishni tashkil etish” to‘g‘risidagi qarorlari hamda mazkur faoliyatga tegishli boshqa me’yoriy-huquqiy hujjatlarda belgilangan vazifalarni amalga oshirishda ushbu dissertatsiya tadqiqoti muayyan darajada xizmat qiladi.

Tadqiqotning Respublika fan va texnlogiyalari rivojlaishing asosiy ustuvor yo‘nalishiga mosligi. Mazkur tadqiqot Respublika fan va texnologiyalarni rivojlantirishning V. “Qishloq xo‘jaligi, biotexnologiya, ekologiya va atrof-muhitni muhofaza qilish” ustuvor yo‘nalishi doirasida bajarilgan.

Muammoning o‘rganilganlik darajasi. Iqlim o‘zgarishini suv omborlarning gidravlik va gidrologik rejimiga ta’sirini baholashga oid ko‘plab tadqiqotlar Respublikamiz va bir qancha xorijiy davlatlarda olib borilgan. Suv omborlarning gidravlik va girologik rejimlarini o‘rganish va ulardagi o‘zgarishlarni o‘rganish yo‘nalishdagi tadqiqotlar S. Aloui, S.L. Beharry, R.K. Jaiswal, X. Lui, T. Lui, M. Yasir, T. Duc Dang, X. Meng, C. Teutschbein, T. Thomas, W. Tian, J. Yao, A. Ashu, R. Allan, I. Bano, O. Barbosa, A. Bliss, F. Choukri, D. Frame, Y. Grusson, S. Hagesmann, C. Li, U. Mandal, D. Maraun, D. Molden, hamda respublikamiz olimlari S.R. Ibatullin, F.K. Khikmatov, M.R. Bakiyev, I.R. Ikramova, A.M. Arifjanov, A.T. Salohiddinov, F.A. Gapparov, I.A. Akhmedxojayeva, Sh. Rahmatullaev, S. Usmanov va boshqa qator olimlar tomonidan olib borilgan va ma’lum ijobiy natijalarga erishilgan.

Shuningdek, iqlim o‘zgarishi bashorat qilish va uning tabiiy resurslarga ta’siri baholash va unga moslashish yo‘nalishidagi tadqiqotlar J.Hansen, M.E.Mann, C.L.Quere, V.Ramatan, S.Seneviratne, K. Hayhoe, D.Chen, P.Zhai, A.Yatagai, G.J. Oldenborgj hamda respublikamiz olimlari B.Nishonov, P.Pulatov, A. Gafurov, M.Sarikulov, S.Abdullayeva, A.Hamidov, N.Hakimov, S.Turaeva va boshqa qator olimlar tomonidan olib borilgan va iqlim o‘zgarishi ta’sirlarini yumshatish va unga qarshi kurashish bo’yicha tavsiyalar ishlab chiqilgan.

Olib borilgan ilmiy izlanishlarda iqlim o‘zgarishi va uning suv resurslari miqdori, suv omborlarining gidrologik rejimiga ta’siri bo‘yicha gidrologik hisoblar amalga oshirilgan. Natijada suv omborlarning ta’minlanganligi yillar, oylar davomida suv miqdorini o‘zgarishini baholash, suv omborlarining ishlash rejimini ishlab chiqish, suv balansini hisoblash usullari ishlab chiqilgan. Iqlim o‘zgarishi suv omborlarining gidravlika va gidrologik rejimlariga ta’sirini baholashda zamonaviy usullarni qo‘llash, ishonchli baholovchi modellardan foydlanib baholash kelajakdagi iqlim senariylarida suv resurslarini barqaror boshqarish masalalari o‘z yechimini kutib qolmoqda.

Dissertatsiya mavzusining dissertatsiya bajargan oliy ta’lim muassasining ilmiy-tadqiqot rejalari bilan bog‘liqligi.

Dissertatsiya tadqiqoti Toshkent irrigatsiya va qishloq xo‘jaligini mexanizatsiyalash muhandislari instituti ilmiy-tadqiqot ishlari rejasining №3-sonli “Global iqlim o‘zgarishi sharoitida suv resurslarini oqilona boqarish, ulardan suv tejamkor texnologiyalar asosida foydalanish va sug‘oriladigan erlarning ekologik-

meliorativ holatini yaxshilashning ilmiy-amaliy asoslarini ishlab chiqish” (2020-2023), № 3,1-sonli “Irrigatsiya tizimlari, gidrotexnik inshootlar va suv omborlarida gidravlik va gidrologik jarayonlarni informatsion texnologiyalar asosida baholashning ilmiy asoslarini ishlab chiqish” (2020-2023),

№ 3,3-sonli “Irrigatsiya tizimlari, gidrotexnik inshootlar va suv omborlarida suv resurslaridan samarali foydalanishning gidravlik va gidrologik jihatlarini baholashning ilmiy asoslarini ishlab chiqish” (2024-2026) mavzularidagi loyihalar doirasida bajarilgan.

Tadqiqot maqsadi. Iqlim o‘zgarishi sharoitida suv omborlarining gidravlik va gidrologik rejimiga bo‘lgan ta’sirni baholashdan iborat.

Tadqiqot vazifalari:

Iqlim o‘zgarishini suv omborining gidravlik va gidrologik rejimiga ta’sirini baholash bo‘yicha olib borilgan tadqiqotlarning analitik tahlili;

Suv hajmlarini baholashda iqlim model (Coupled Model Intercomparison Project 6 (CMIP6)) ma’lumotlarini moslashtirish (bias correction) va tahlil qilish;

Daryo havzasidagi iqlim o‘zgarishini suv omborning gidravlik va gidrologik rejimiga ta’sirini SWAT model orqali baholash;

Iqlim o‘zgarishi sharoitida suv omborlarning suv hajmlarini o‘zgarishini baholash bo‘yicha tavsiyalar ishlab chiqish.

Tadqiqot obyekti sifatida Qashqadaryo viloyati, Shahrisabz tumanidagi Hisorak suv ombori olingan.

Tadqiqot predmeti yog‘ingarchilik shakllari va intensivligining o‘zgarishi, havo haroratining ko‘tarilishi, qor-qor suvining erish dinamikasi, suv oqimining mavsumiy va yillik taqsimoti, suv yig‘ilishi va chiqarilishi balansining o‘zgarishi, omborlar to‘lish va bo‘shash (irrigatsion) rejimlari, iqlim senariylari asosida suv omborlarining ekspluatatsiya samaradorligiga, suv resurslarining mavjudligi va ularning taqsimlanishiga ta’sir etuvchi omillar tashkil etadi.

Tadqiqot usullari. Tadqiqot jarayonida mavjud ma’lumotlarni trend tahlili, iqlim model ma’lumotlarini xatoliklarini to‘g‘irlash (bias correction), kalibratsiya va validatsiya, GAT texnologiyalari, statistik tahlil hamda gidravlika va gidrologik modellashtirish (SWAT modeli orqali) usullaridan foydalanildi.

Tadqiqotning ilmiy yangiligi quyidagilardan iborat:

machine learning algoritmlaridan foydalanib, gidrologik model ma’lumotlarini kalibratsiya va validatsiya qilish uchun dasturiy ta’minot ishlab chiqilgan;

CMIP6 global iqlim o‘zgarishi senariylarining (SSP1-2.6 va SSP5-8.5) prognoz ma’lumotlari ilk bor Oqsuv suv daryo havzasi uchun statistik bias correction usuli yordamida moslashtirilgan;

iqlim o‘zgaruvchanligini inobatga olib, suv omborlarining gidravlik va gidrologik rejimlarini o‘zgarishini bashorat qilishda SWAT model parametrlari takomillashtirilgan;

turli suvlilik davrlar uchun takomillashgan SWAT modeli asosida Hisorak suv omborining ishlash rejimi ishlab chiqilgan.

Tadqiqotning amaliy natijalari

Iqlim model ma’lumotlarining xatoliklarini to‘g‘irlovchi (bias correction) dasturiy ta’minot ishlab chiqilgan;

Iqlim o‘zgarishini suv resurslariga bo‘ladigan ta’sirlarini baholash uchun python dasturlash tili yordamida gidrologik model ishlab chiqilgan;

Iqlim o‘zgarishing suv omborlarning gidravlik va gidrologik rejimiga ta’siri baholash usuli takomillashtirilgan;

Tadqiqot natijalarining ishonchliligi. Tadqiqot natijalarining ishonchliligi nazariy yechimlarni ishlab chiqishda umum qabul qilingan gidravlik qonunlar va modellashtirish usullarga asoslanganligi, olingan natijalar amalda statistik ko‘rsatgichlar bilan tahlil qilinganligi va natijalar ishonchlili yuqori ekanligi hamda boshqa olimlar tomonidan olingan ma’lumotlar bilan taqqoslab tekshirilganligi bilan izohlanadi.

Tadqiqot natijalarining ilmiy va amaliy ahamiyati. Tadqiqot natijalarining ilmiy ahamiyati python dasturlash tilida iqlim model ma’lumotlarini xatoliklarni to‘g‘irlovchi (bias correction) dasturiy ta’minot ishlab chiqish asosida suv omborlaridagi iqlim o‘zgarishi tahlil aniqligi oshirildi.

Shuningdek, iqlim o‘zgaruvchanligini inobatga olib, suv omborning gidravlik va gidrologik rejimiga ta’siri baholash uchun zarur bo‘lgan SWAT model parameterlari takomillashtirildi.

Tadqiqot natijalarining amaliy ahamiyati iqlim o‘zgarishini suv omborlarining gidravlik va gidrologik rejimiga ta’sirini modellashtirish asosida kelajakda suv omborlariga keladigan suv sarfi, suv omborlardagi suv sathini o‘zgarishini hamda ko‘p suvlilik va kam suvlilik davrlarni oldindan aniqlash orqali suv omborlarni boshqaruvini yanada samaraliroq tashkil qilish imkonini berishi bilan izohlanadi.

Tadqiqot natijalarining joriy qilinishi. “Iqlim o‘zgarishini suv omborlarining gidravlikva gidrologik rejimiga ta’sirini baholash” bo‘yicha olingan ilmiy tadqiqot natijasi asosida:

suv ombor havzasi uchun iqlim o‘zgarishi model ma’lumotlari tahlil qilindi va ulardagi xatoliklar statistik usul (bias correction) dan foydlanib to‘g‘irlandi (O‘zbekiston Respublikasi Suv xo‘jaligi vazirligining 2024 yil 21 dekabr 02/13-5019 sonli ma’lumotnomasi). Natijada suv ombor havzasi bo‘yicha mavjud iqlim model ma’lumotlar va ularning tahlil aniqligi oshirildi.

suv omborlarining gidravlik va gidrologik rejimlarini o‘zgarishini bashorat qilishda model parametrlari takomillashtirildi (O‘zbekiston Respublikasi Suv xo‘jaligi vazirligining 2024 yil 21 dekabr 02/13-5019 sonli ma’lumotnomasi). Natijada iqlim o‘zgarishini suv omborlarining gidravik va gidrologik rejimiga ta’siri baholash aniqligi oshirildi.

turli suvlilik davrlar uchun takomillashgan SWAT modeli asosida suv omborining ishlash rejimi ishlab chiqildi (O‘zbekiston Respublikasi Suv xo‘jaligi vazirligining 2024 yil 21 dekabr 02/13-5019 sonli ma’lumotnomasi). Natijada iqlim o‘zgarishini keskinlashuvi jarayonida suv omborning ishlash samaradorligi oshirildi.

Tadqiqot natijalari aprobatsiyasi. Mazkur tadqiqot natijalari 3 ta xalqaro va 2ta Respublika ilmiy-amaliy anjumanlarida muhokamadan o‘tkazilgan.

Tadqiqot natijalarinining e’lon qilinishi. Dissertatsiya ishlari bo‘yicha 9 ta chop etilgan. O‘zbekiston Respublikasi Oliy attestatsiya komissiyasining doktorlik dissertatsiyalari asosiy ilmiy natijalarini chop etish tavsiya etilgan ilmiy nashrlarda

9 ta, jumladan 5 ta Respublika va 2 ta xorijiy konferensiya hamda jurnallarda nashr qilingan, 2ta mualliflik guvohnomasi olingan.

Dessertatsiya tuzilishi va hajmi. Dissertatsiya ishi kirish, to‘rtta bob, xulosa, foydalanilgan adabiyotlar, ilovalalardan iborat va dissertatsiya ishi 93 betni tashkil qiladi.

DISSERTATSIYANING ASOSIY MAZMUNI

Kirish qismida dissertatsiya mavzusining dolzarbligi va zaruriyati asoslangan, tadqiqot maqsadi va vazifalari xamda obyekt va predmetlari shakllantirilib, tadqiqotning O‘zbekiston Respublikasi fan texnologiyalarini rivojlantirishning ustuvor yo‘nalishlariga mosligi ko‘rsatilgan, tadqiqotning ilmiy yangiligi va tadqiqotning amaliy natijalari bayon qilingan. Olingan natijalarning nazariy va amaliy ahamiyati ochib berilgan, tadqiqot natijalarini joriy qilinganligi, nashr etilgan ishlar va dissertatsiyaning tuzilishi bo’yicha ma’lumotlar keltirilgan.

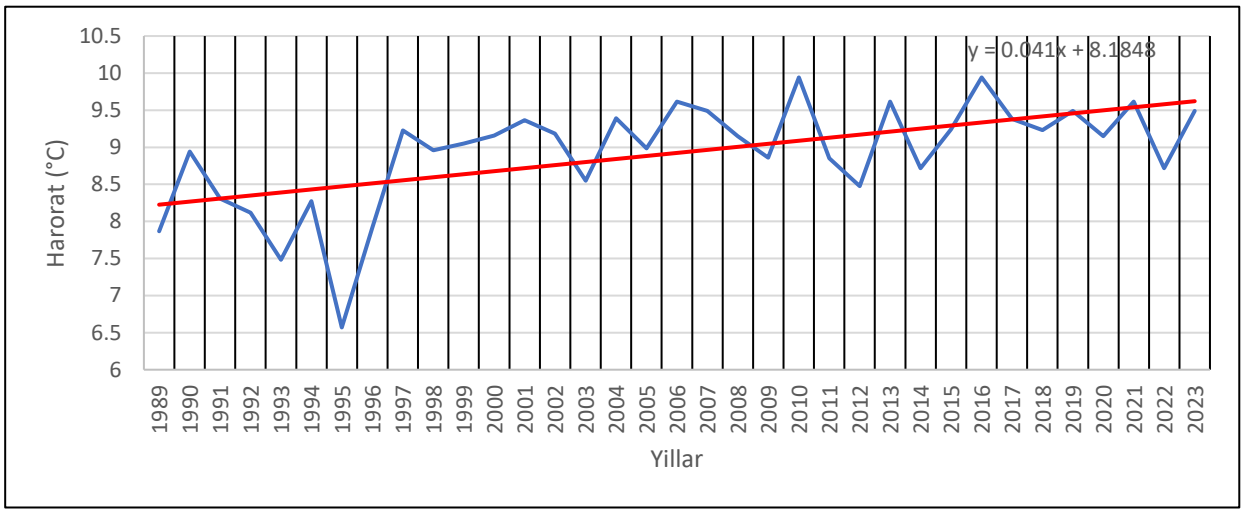
Dissertatsiyaning “**Iqlim o‘zgarishini suv omborining gidravlik va gidrologik rejimiga ta’sirini baholash bo‘yicha olib borilgan tadqiqotlarning analitik tahlili**” deb nomlangan birinchi iqlim o‘zgarishini suv omborlarining gidravlik va gidrologik rejimlari ta’siri bo‘yicha olib borilgan tadqiqotlarni ko‘rib chiqishga va ushbu ta'sirlarni baholash uchun ishlatiladigan modellashtirish yondashuvlarini tahlil qilishga bag‘ishlangan. Birinchi navbatda suv omborlari nima uchun muhimligini va yog'ingarchilik, evapotranspiratsiya, qor/muzlik dinamikasi va oqimlarni ekstremal o‘zgarishi, ularni saqlash va boshqaruv xavflarni va ularni ta’sirini aniqlash va baholash uchun modelga asoslangan tahlil muhim ahamiyat kasb etadi.

Adabiyot tahlilining asosiy xulosasi shundan iboratki, SWAT modeli suv omborlar bo‘yicha olib borilgan tadqiqotida eng asosiylaridan biri bo‘lib xizmat qilib kelmoqda, jumladan: ushbu bobda Eron (Zayandeh-Roud), Xitoy (Yangtze va Yalong), Tailand (Mun), Hindiston (Subarnarekha, Narmada), Marokash (Tleta), Yaponiya (Sagami), Kanada (Shellmouth), Portugaliya (Vigia/Monte Novo), Koreya (Osan), Karib dengizi (Navet) va boshqalarda olib borilgan tadqiqotlarda kalibirlash/tasdiqlash (ko‘p hollarda SWAT modelidagi SUFI-2) va iqlim hamda boshqaruv senariylardan foydalanilgan.

Shuningdek, adabiyot tahliliga ko‘ra, aksariyat tadqiqotlarda iqlim senariylari prognozlarining RCP (masalan 2.6/4.5/8.5) foydalanilgan bo‘lsa, qolgan tadqiqotlarda ko‘proq CMIP6 SSP (ayniqsa SSP1-2.6 va SSP5-8.5) senariylari va ularning prognozlaridan foydalanilgan, bu iqlim o‘zgarishi, ularni ta’siri va havflarini yana aniqroq baholash imkonini yaratadi. Bu yerda umumlashtirilgan SWAT+senariy tadqiqotlarining olib borishdagi tendensiya shuni ko‘rsatadiki, SWAT va senariyga asoslangan metodologiya ushbu tadqiqot tanlab olindi, chunki ular keng qo‘llanilgan, kalibrlash/tasdiqlash uchun shaffof, CMIP6 SSP senariylari bilan ishlash orqali iqlim o‘zgarishi va ularning suv omborlarning ishlash rejimlariga ta’sirini baholash va ishlash rejimini optimallashtirishga imkoniyat yaratadi.

Dissertatsiyaning “**Suv hajmlarini baholashda iqlim model (Coupled Model Intercomparison Project 6 (CMIP6)) ma’lumotlarini moslashtirish (bias correction) va tahlil qilish**” mavzusidagi ikkinchi bobida tadqiqot hududida iqlim

model ma’lumoti xatoliklari to‘g‘irlandi va iqlim model hamda Uzgidromet ma’lumotlari uning tahlili olib borildi. 1989 yildan 2023 yilgacha o‘rtacha harorat yildan-yilga sezilarli tebranishlarni ko‘rsatadi, ba’zi yillarda keskin pasayish yoki o‘sish kuzatiladi. Biroq, umumiy tendentsiya, yuqoriga ko‘tarilgan qizil chiziq bilan ko‘rsatilgandek, vaqt o‘tishi bilan o‘rtacha haroratning asta-sekin o‘sishini ko‘rsatadi. Trend chizig‘ining qiyaligi o‘rganish davrida haroratning yiliga taxminan 0.041°C ga o‘rtacha yillik o‘sishini ko‘rsatadi. Moviy chiziq yog‘ingarchilikning yildan-yilga sezilarli o‘zgaruvchanligini ko‘rsatadi, ba’zi yillarda cho‘qqilar (masalan, 1200 mm dan yuqori) va boshqalarida keskin pasayish (masalan, 600 mm dan past) kuzatiladi. Ushbu o‘zgaruvchanlikka qaramay, qizil tendentsiya kuzatilgan davrda yillik yog‘ingarchilikning biroz pasayish tendentsiyasini ko‘rsatadi. Trend chizig‘ining qiyaligi (-1,6216) yog‘ingarchilikning yiliga o‘rtacha 1,62 mm ga

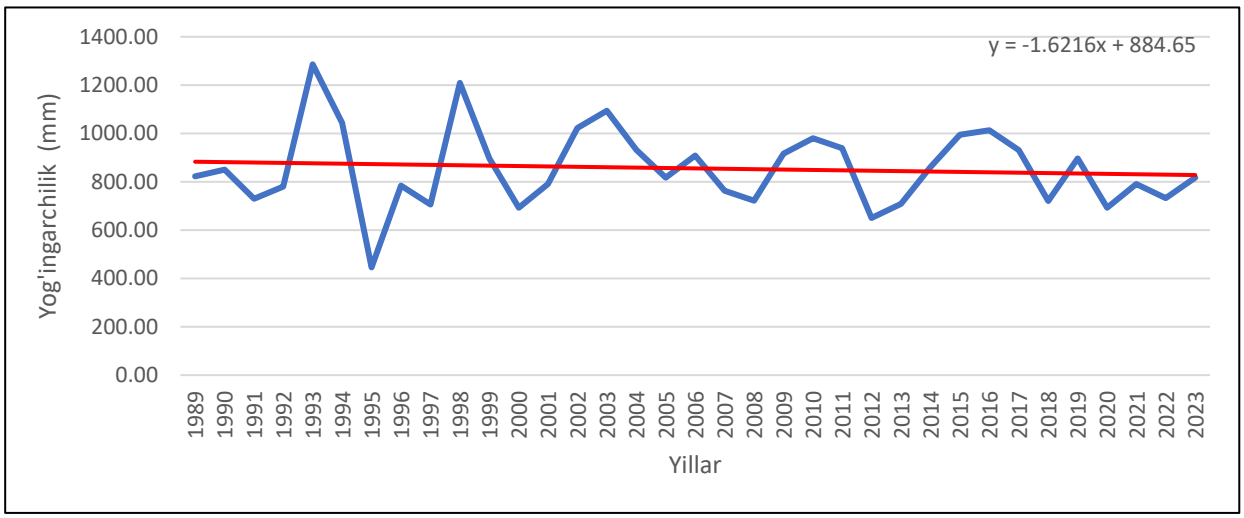


kamayishini ko‘rsatadi.

1-rasm. 1989 yildan 2023 yilgacha bo‘lgan yillardagi o‘rtacha yillik harorat tendentsiyasi (Uzgidromet)

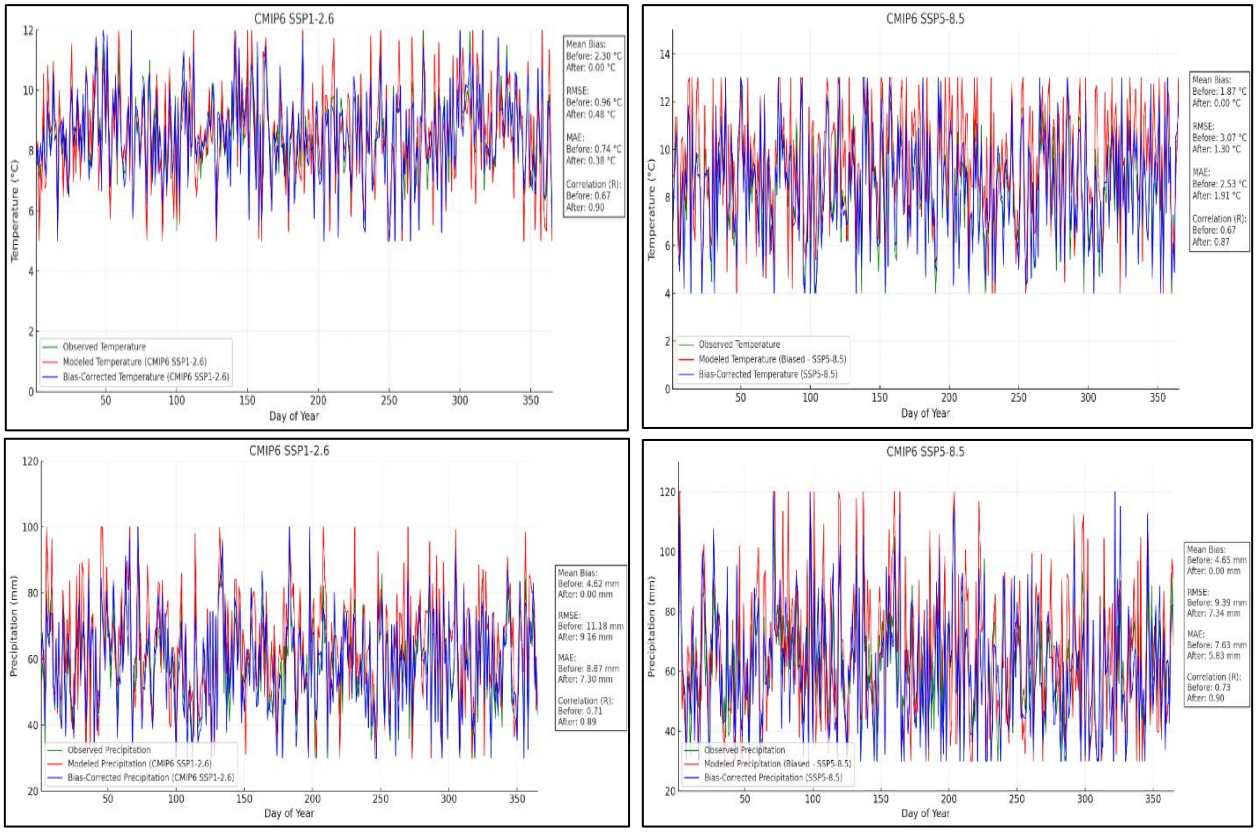
2-rasm. 1989 yildan 2023 yilgacha bo‘lgan yillardagi o‘rtacha yillik yog‘ingarchilik tendentsiyasi (Uzgidromet).

Yuqori chap panelda SSP1-2.6 stsenariysi uchun harorat ma’lumotlari ko‘rsatiladi. U kuzatilgan haroratni (yashil), modellashtirilgan haroratni (qizil) va



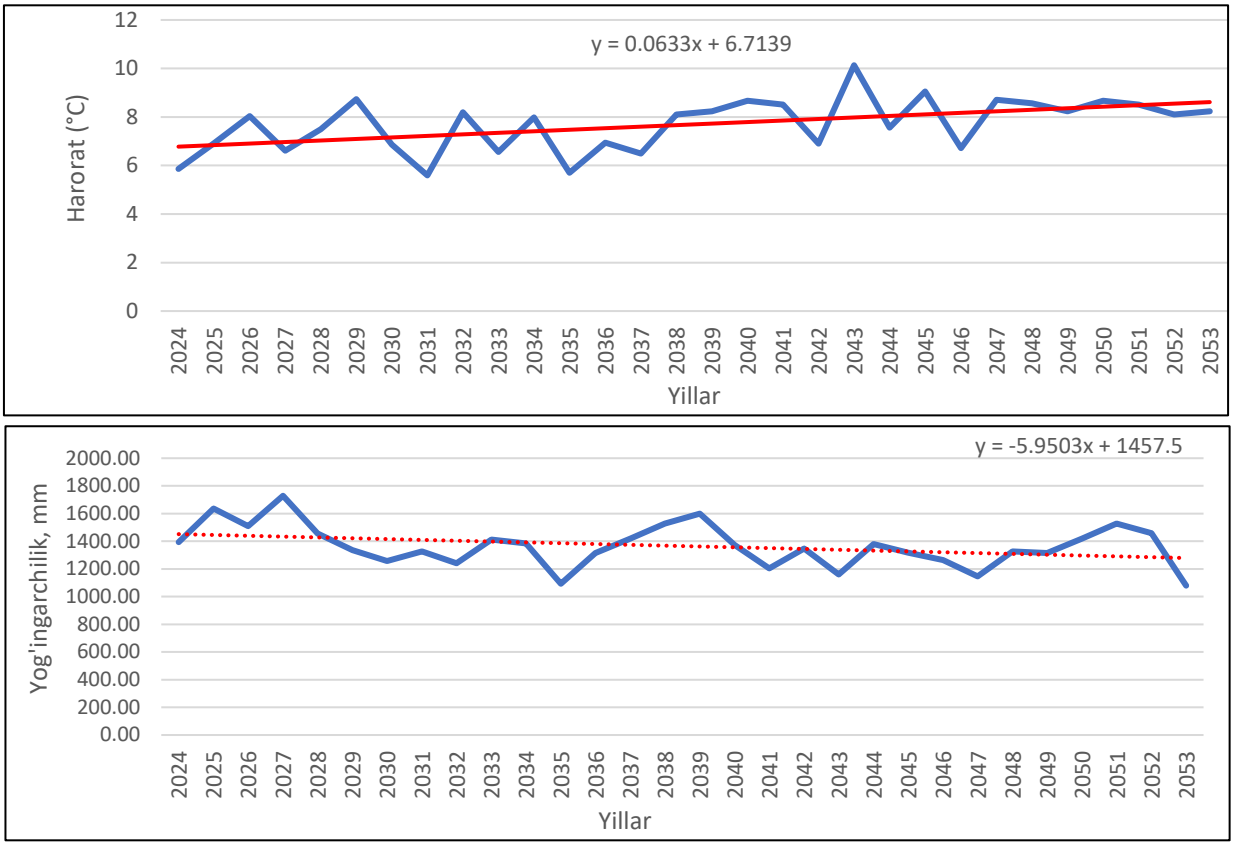
noto‘g‘ri tuzatilgan haroratni (ko‘k) ko‘rsatadi. O‘rtacha moyillik 0,92 °C dan 0,00°C gacha yaxshilanadi. Ildiz o‘rtacha kvadrat xatosi (RMSE) 2,24 °C dan 2,04°C gacha kamayadi va o‘rtacha mutlaq xato (MAE) 1,77 °C dan 1,62 °C gacha kamayadi. Korrelyatsiya koeffitsienti (R) 0,87 da barqarorligicha qolmoqda. Ushbu statistik ma’lumotlar shuni ko‘rsatadiki, noaniqlikni to‘g‘irlash modellashtirilgan haroratni xatolar va noto‘g‘rilikni kamaytirish orqali kuzatilgan qiymatlarga yaqinroq moslashtiradi.

Yuqori o‘ng panelda yuqori emissiya kelajagini ifodalovchi SSP5-8.5 stsenariysi uchun harorat ma’lumotlari ko’rsatilgan. Yo‘nalishni to‘g‘irlagandan so‘ng, o‘rtacha moyillik 1,87 °C dan 0,00 °C gacha kamayadi. RMSE 3,07 °C dan 2,43 °C gacha, MAE 2,53 ° C dan 1,91 °C gacha kamayadi. Korrelyatsiya koeffitsienti 0,83 da doimiy bo‘lib qoladi. Ushbu natijalar shuni ko‘rsatadiki, noto‘g‘ri chiziqni tuzatish, hatto ekstremal emissiya senariysi ostida ham modellashtirilgan va kuzatilgan haroratlarni moslashtirishni yaxshilaydi.



3- rasm. ikki xil CMIP6 iqlim senariysi bo‘yicha harorat yoki yog‘ingarchilik ma’lumotlari to‘g‘rilangan: SSP1-2,6 (yuqori chap va pastki chap) va SSP5-8,5 (yuqori o‘ng va pastki o‘ng).

Keyingi 30 yilda, temperatura 1.8 °C ga ko‘tarilishi qayt etildgan. Bu ko‘rsatgich yiliga 0.06 °C bo‘lishi bashorat qilingan. Yaqin 30 yilda, Hisorak suv ombori havzasida yog‘ingarchilik miqdori 176.6 mm pasayishi bashorat qilingan, va yiliga o‘rtacha 6.1 mm pasayish kuzatiladi (4-rasm).



4-rasm. CMIP6 SSP1-2.6 senariysi: temperatura va yog‘ingarchilik

Dissertatsiyaning “**Daryo havzasidagi iqlim o‘zgarishini suv omborning gidravlik va gidrologik rejimiga ta’sirini SWAT model orqali baholash**” mavzusidagi uchinchi bobida iqlim o‘zgarishining suv omborlarning gidravlik va gidrologik rejimlariga ta’siri SWAT modeli orqali baholandi. Tadqiqot davomida SWAT modeli tadqiqot natijalari aniqligi va ishonchliligini oshirish maqsadida turli xil statistik ko‘rsatgichlardan foydalanildi va ularni tahlili olib borildi. Tadqiqot davomida SWAT modeli natijalarining aniqligi va ishonchliligini oshirish maqsadida turli statistik ko‘rsatkichlar qo‘llanildi va tahlil qilindi. SWAT modeli tomonidan simulyatsiya qilingan gidrologik sikl suv balansi tenglamasiga asoslanadi:

$$SW_t = SW_0 + \sum_{i=1}^{t}\left(R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}\right) \quad (1)$$

Bu yerda: **SWt** - tuproqdagi yakuniy suv miqdori, **SW0** -tuproqdagi boshlang‘ich suv miqdori, **t**-vaqt (kunlarda), **Rday**-kunlik yog‘ingarchilik miqdori, **Qsurf** - kunlik yuzaki oqim, **Ea**-kunlik evapotranspiratsiya (ET), **Wseep** kunlik infiltratsiya (chuqur qatlamlarga sizib kirish), **Qgw**- kunlik grunt suvlarining qaytish oqimi va barcha birliklar millimetr (mm)da berilgan.

Bundan tashqari, SWAT modelining natijalar sifati va ish faoliyatini baholash uchun bir nechta statistik ko‘rsatkichlardan foydalaniladi, jumladan **NS (Nash-Sutcliffe samaradorlik koeffitsienti)**, **R² (aniqlik koeffitsienti)**, **p-faktor** va **r-**

faktor. Nash–Sutcliffe samaradorlik ko‘rsatkichi SWAT modelini kalibrlashda muhim ahamiyatga ega, chunki u modellashtirilgan gidrogrammaning kuzatilgan real ma’lumotlarga qanchalik mos kelishini bitta aniq raqam orqali ifodalaydi.

$$NS = 1 - \left[\frac{\sum_{i=1}^{n}\left(Q_{obs}(i) - Q_{sim}(i)\right)^2}{\sum_{i=1}^{n}(Q_{obs}(i) - \bar{Q}_{obs})^2}\right] \quad (2)$$

Aniqlik koeffitsienti (**R²**) SWAT modellashtirishida modellashtirilgan oqim miqdorining kuzatilgan qiymatlarga naqsh va bog‘liqlik kuchi jihatidan qanchalik mos kelishini baholash uchun qo‘llaniladi. U kuzatilgan ma’lumotlardagi dispersiyaning qanchalik qismi model natijalari orqali tushuntirilishini ifodalaydi.

$$R^2 = \frac{\left[\sum_{i=1}^{n}(Q_{\text{obs}}(i) - \bar{Q}_{\text{obs}})(Q_{\text{sim}}(i) - \bar{Q}_{\text{sim}})\right]^2}{\sum_{i=1}^{n}(Q_{\text{obs}}(i) - \bar{Q}_{\text{obs}})^2 \sum_{i=1}^{n}(Q_{\text{sim}}(i) - \bar{Q}_{\text{sim}})^2} \quad (3)$$

Yana bir ko‘rsatkich **p-faktor**, SWAT modellashtirishida modelning noaniqlik diapazoni kuzatilgan ma’lumotlarni qanchalik yaxshi qamrab olishini baholash uchun qo‘llaniladi. U kalibrlash jarayonida hosil bo‘lgan 95% bashorat noaniqligi oralig‘iga tushgan kuzatilgan oqim qiymatlarining ulushini ko‘rsatadi.

$$\text{p} - \text{factor} = \frac{\sum_{i=1}^{N} I(O_t \in [L_t,\ U_t])}{N} \quad (4)$$

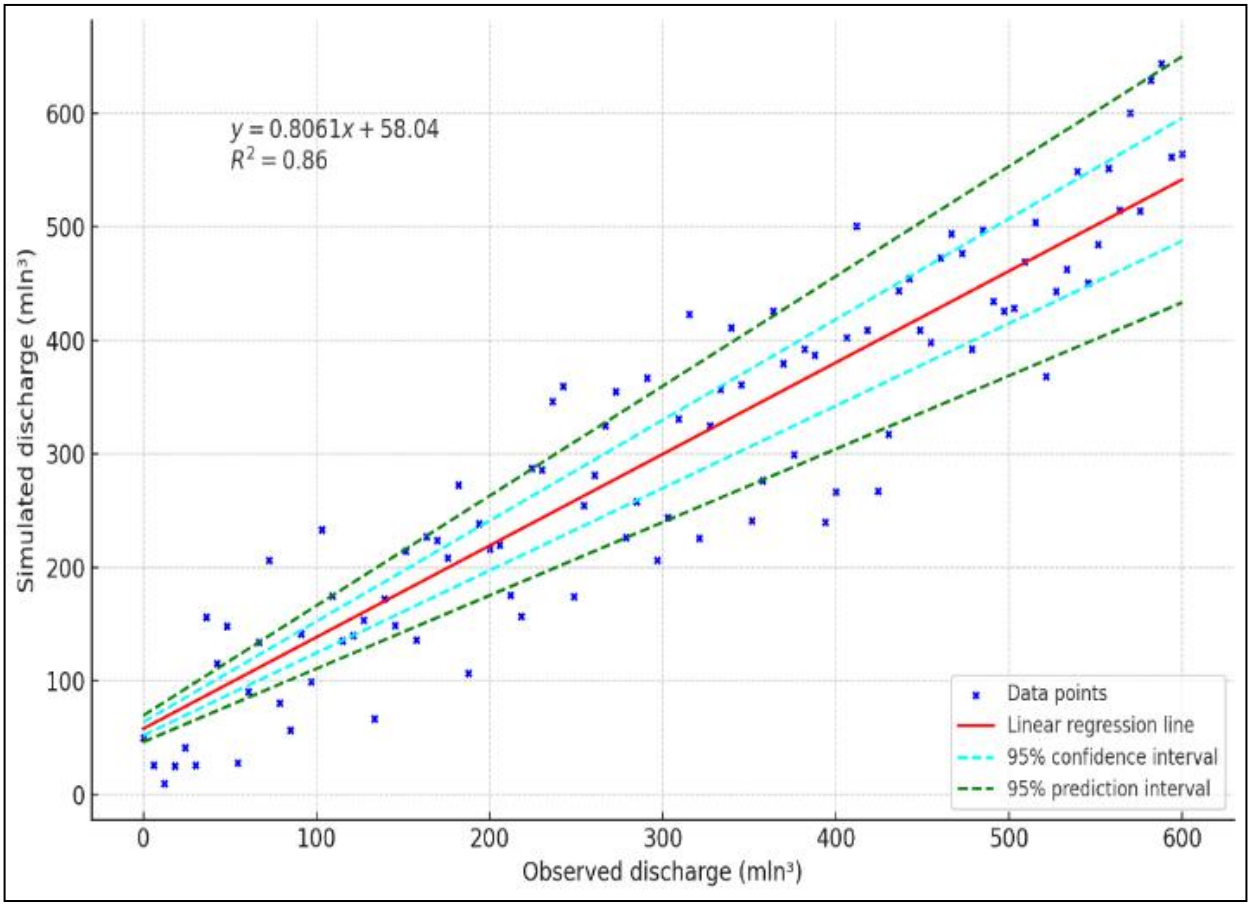
r-faktor SWAT modellashtirishida 95% bashorat noaniqligi oralig‘ining kengligini kuzatilgan ma’lumotlar o‘zgaruvchanligiga nisbatan baholash uchun qo‘llaniladi. Aniqrog‘i, bu ko‘rsatkich ushbu noaniqlik diapazonining o‘rtacha qalinligini kuzatilgan oqim miqdorining standart og‘ishiga bo‘lish orqali aniqlanadi.

$$\text{r} - \text{factor} = \frac{\frac{1}{n}\sum_{i=1}^{n}[\text{U}_{95}(t) - \text{L}_{95}(t)]}{\sigma_{\text{obs}}} \quad (5)$$

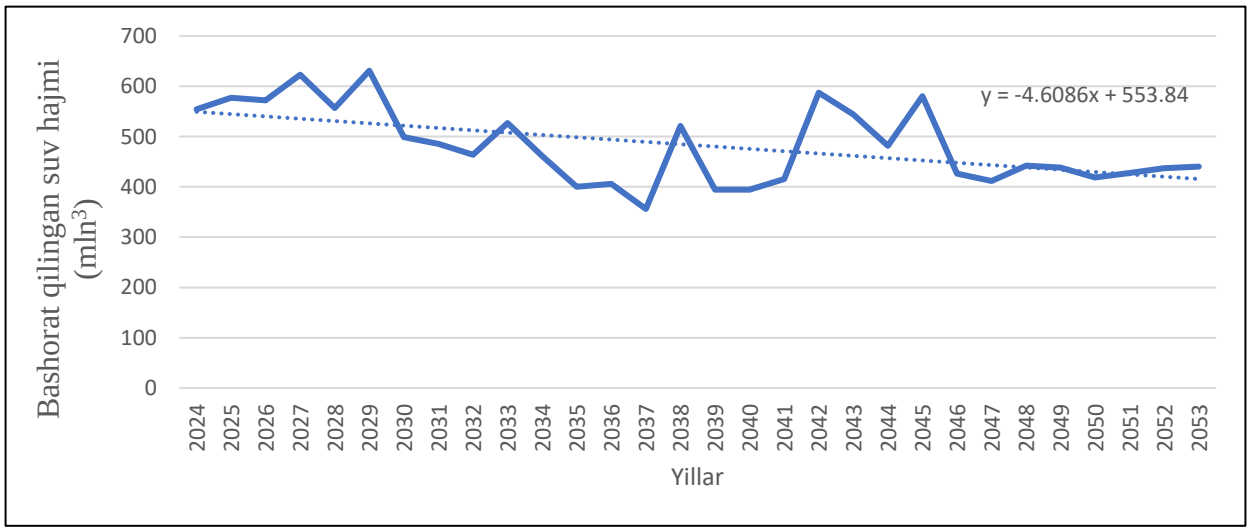
Chap panelda, suv sarfi ma’lumotlari 1986 yildan 2000 yilgacha bo‘lgan yillar bo‘yicha chizilgan bo‘lib, sekundiga kubometr (m³/s) bilan o‘lchangan. Yashil chiziq kuzatilgan ma’lumotlarni, qizil chiziq esa SWAT modeli simulyatsiyasini ifodalaydi. Ikki chiziq butun davr davomida bir-biriga chambarchas bog‘liq bo‘lib, kuzatilgan va modellashtirilgan ma’lumotlar o‘rtasidagi mustahkam kelishuvdan dalolat beradi. Ikkala ma’lumot to‘plami ham sezilarli yillar oralig’ida o‘zgaruvchanlikni ko‘rsatadi, ma’lum yillarda (masalan, taxminan 1987 va 1996 yillarda) oqim eng yuqori darajaga etadi va boshqalarida (masalan, 1998 va 2000 yillarda) kamayadi. Bu shuni ko‘rsatadiki, SWAT modeli daryo oqimining vaqtinchalik tendentsiyalarini samarali tarzda qamrab oladi.

O‘ng panelda tarqalish sxemasi kuzatilgan razryadni (x o‘qi) va simulyatsiya qilingan oqimni (y o‘qi) taqqoslaydi. Qizil chiziq chiziqli regressiya chizig‘ini tenglama bilan ifodalaydi y=0,8061x+58,04. Unga ko‘ra, R^2 0.86 qiymati kuzatilgan

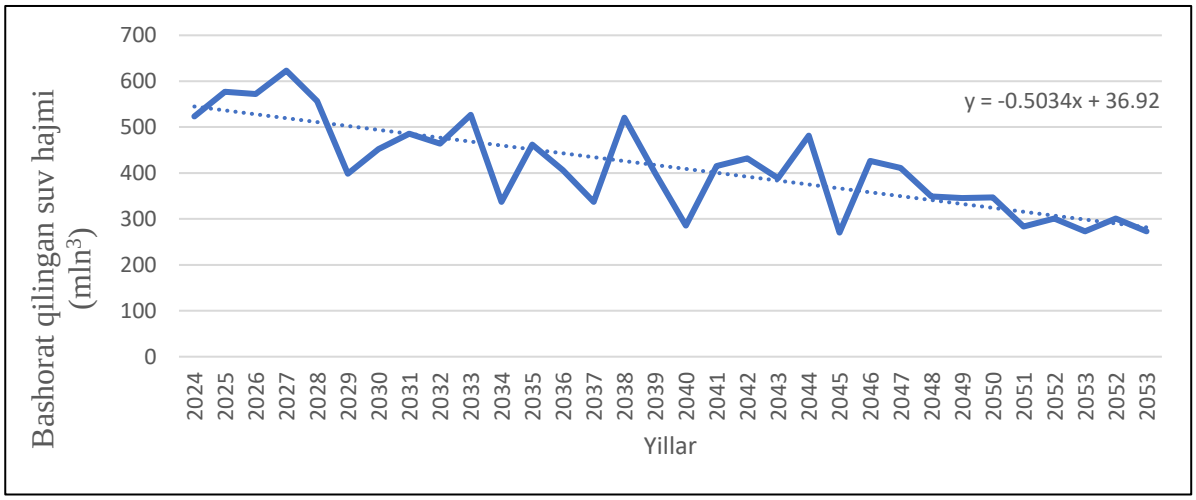
va simulyatsiya qilingan ma’lumotlar o‘rtasidagi kuchli ijobiy korrelyatsiyani ko‘rsatadi. 95% ishonch oralig‘i (qattiq yashil chiziqlar) va 95% bashorat qilish oralig‘i (chiziqli yashil chiziqlar) regressiya chizig‘i atrofidagi o‘zgaruvchanlik oralig‘ini ko‘rsatadi. Ma’lumotlar nuqtalari ishonch va bashorat oraliqlari ichida joylashgan bo‘lib, bu modelning aniqligini yanada tasdiqlaydi (rasm 7). Natijalarga ko‘ra SSP1-2.6. senariysida 17.7% kamaygan, SSP5-8.5 senariysida esa bu ko‘rsatgich 28.5% ko‘rsatgichni qayt etgan (Rasm 8,9).



7-rasm. Uzgidromet va SWAT model ma’lumotlari tahlili



Rasm 8. SSP1-2.6. senariysi kesimida suv hajmini o‘zgarishi

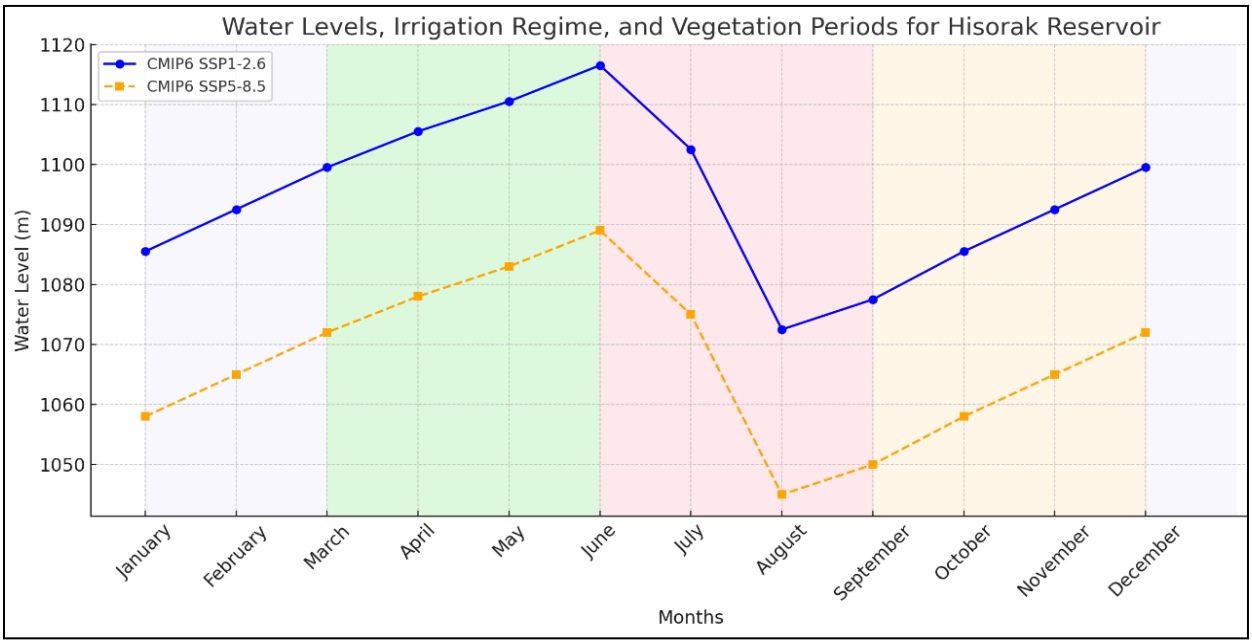


Rasm 9. SSP5-8.5 senariysi kesimida suv hajmini o‘zgarishi

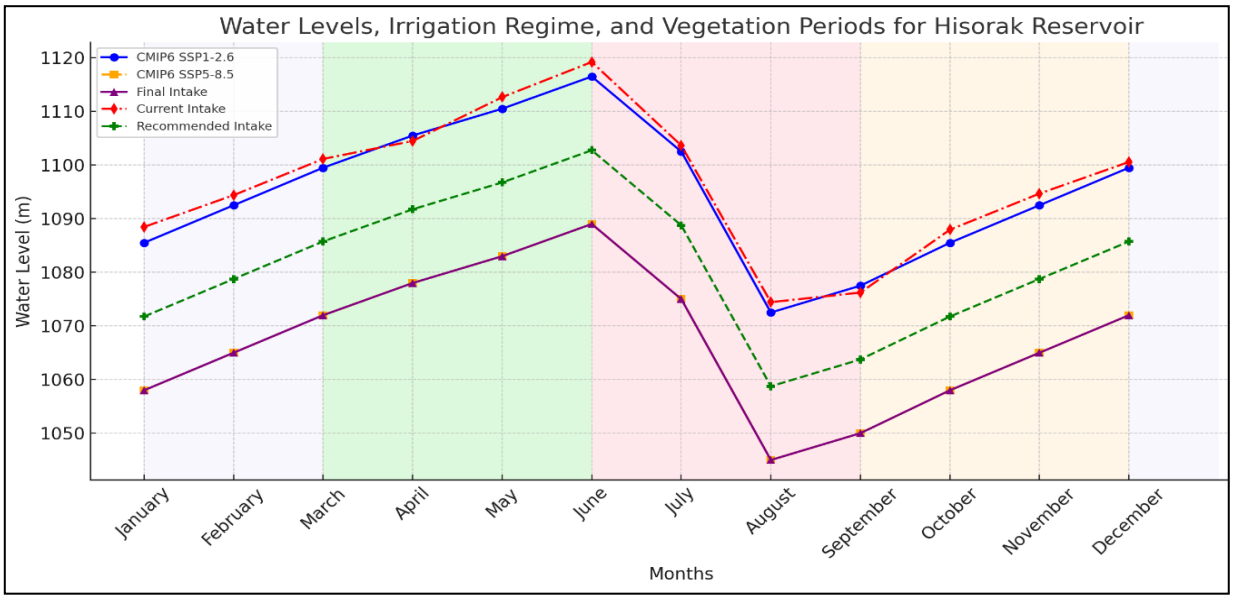
10-rasmda Hisor suv omborida ikkita iqlim ssenariysi SSP1-2.6 (past emissiya) va SSP5-8.5 (yuqori emissiya) sharoitida bashorat qilingan suv sathining o‘zgarishi SWAT modeli asosida baholangan. SSP1-2.6 senariysi bo‘yicha suv sathi yil davomida nisbatan yuqori va barqaror (1100-1120 m) bo‘lib, iyul oyida eng yuqori nuqtaga yetadi va mavsumiy o‘zgarishlar unchalik sezilmaydi, bu esa yetarli yog‘ingarchilik va oqim mavjudligini ko‘rsatadi. Aksincha, SSP5-8.5 ssenariysi ostida umumiy suv sathi pastroq (1060-1090 m) bo‘lib, ayniqsa yoz oxirida keskin pasayish va katta mavsumiy o‘zgarishlar kuzatiladi. Buning sababi sifatida bug‘lanishning ortishi, qor suvlarining kamayishi va oqimning buzilishi ko‘rsatilmoqda. Bu holat, ayniqsa, yoz oxiri va kuzda suv tanqisligi xavfining ortishini anglatadi. Natijalar kelajakdagi xavflarni kamaytirish uchun iqlimga chidamli suv resurslarini boshqarish strategiyalarining muhimligini ta’kidlaydi (Rasm 10).

Rasmda Hisorak suv omborida SSP1-2.6 va SSP5-8.5 iqlim ssenariylari sharoitida suv sathi va suv olish (iste’mol)ning mavsumiy o‘zgarishlari, shuningdek, amaldagi va tavsiya etilgan suv olish miqdorlari bilan taqqoslangan holati ko‘rsatilgan. Bahor oylarida sug‘orish ehtiyoji oshgani sari suv olish miqdori bosqichma-bosqich ortadi, shu bilan birga suv omboridagi sath har ikkala ssenariyda ham barqaror va yetarli bo‘lib qoladi. Yoz boshida suv sathi maksimal darajaga yetadi va iyun oyida suv olish eng yuqori nuqtaga chiqadi. Biroq, avgust oyiga kelib, suv olish keskin kamayadi va taxminan 1045 metrga tushib ketadi, bu esa tavsiya etilgan va prognoz qilingan suv sathlaridan past bo‘lib, ortiqcha foydalanish, oqimning kamayishi va SSP5-8.5 ssenariysi sharoitida kuchaygan bug‘lanish natijasida sezilarli darajada kamayishni anglatadi. Kuz faslida esa suv olish miqdori asta-sekin tiklanadi, chunki sug‘orish ehtiyoji pasayadi va suv sathi bosqichma-bosqich ko‘tariladi. Qishda suv olish eng past darajada bo‘lib, bu davr suv omborining keyingi mavsumga tayyorlanishi uchun tabiiy tiklanish bosqichi sifatida

xizmat qiladi. E’tiborga molik jihati shundaki, tavsiya etilgan suv olish chizig‘i yil davomida SSP5-8.5 sathidan doimiy ravishda past bo‘lib, bu usul yanada optimallashtirilgan va barqaror suv olish strategiyasini aks ettiradi. Ushbu rejimga rioya qilish, ayniqsa, yoz oxiridagi tanqislikning oldini olishda foydali bo‘lib, hozirgi va kelajakdagi iqlim sharoitida suv xavfsizligini ta’minlashda amaliy yechim sifatida xizmat qiladi (Rasm 11).



Rasm 10. Hisorak suv omborida CMIP6 SSP1-2.6 va CMIP6 SSP5-8.5 senariylari bo‘yicha suv sathining o‘zgarishi



Rasm 11. Hisorak suv ombori uchun vegetatsiya davrlarida sug‘orish rejimi

Dissertatsiyaning “**Iqlim o‘zgarishining suv omboriga ta’sirini baholash bo‘yicha tavsiyalar ishlab chiqish**” mavzusidagi to‘rtinchi bobida iqlim o‘zgaruvchanligi va uzoq muddatli iqlim o‘zgarishi sharoitida Hisorak suv omborini barqaror boshqarish muammolari va imkoniyatlari yoritilgan. SWAT modelini

xatolari tuzatilgan CMIP6 prognozlari (SSP1-2.6 va SSP5-8.5) bilan qo‘llash orqali tadqiqot yillik suv oqimining kamayishi, suv omborlari sathining mavsumiy siljishi va ekstremal gidrologik hodisalar xavfining ortishi haqida aniq dalillarni aniqlashga imkon yaratadi. Tadqiqot natijalariga ko‘ra, yuqori emissiya senariylarida suv hajmini 28,5% gacha qisqarishini ko‘rsatadi, bunda sezilarli mavsumiy tebranishlar, masalan, og‘ir holatlarda yozda sathining 1060 m dan pastga tushishi bashorat qilingan. Ko‘pgina hollarda, menejerlar suv omborlari sathining 1065 m yoki 1070 m kabi chegaralardan pastga tushishiga yo‘l qo‘ymaslik uchun iyun va iyul oylarida eng yuqori oylik sug‘orishni 10-15% ga kamaytirishlari tavsiya qilinad, bu o‘z o‘rnida avgust va sentyabrgacha barqaror suv ta’minotini saqlashga yordam beradi.

Tadqiqot natijalariga ko‘ra bug‘lanish va cho‘kindi muammolarini kamaytirish uchun real vaqt rejimida gidrologik monitoring, erta ogohlantirish tizimlari va infratuzilmani yangilash kabi moslashuvchan va ma’lumotlarga asoslangan strategiyalar zarurligini ta’kidlaydi. Qishloq xo‘jaligida suvdan foydalanishga alohida e’tibor qaratilib, sug‘orish samaradorligini oshirish, qurg‘oqchilikka chidamli ekinlarni ko‘paytirish, ekish jadvallarini yangi gidrologik o‘zgarishga moslashtirish tavsiya qilinadi.

XULOSALAR

Ushbu dissertatsiya doirasida Hisorak suv omborida olib borilgan tadqiqotlar asosida quyidagi xulosalar qilindi:

1. Hisorak suv ombori iqlim o‘zgarishi tufayli gidrologik rejimida sezilarli o‘zgarishlarga uchradi. Yog‘ingarchilikning kamayishi, haroratning ko‘tarilishi va oqim hajmlarini (Oqsuv daryosi) o‘zgarishi 1990 yildan 2020 yilgacha suv oqimining barqaror pasayishiga olib keldi.

2. CMIP6 senariylariga (SSP1-2.6 va SSP5-8.5) xatolari to‘g‘irlashni qo‘llash iqlim prognozlarining ishonchliligini sezilarli darajada oshirdi. Yuqori emissiya yo‘lida (SSP5-8,5) noaniqlikni tuzatish ayniqsa samarali bo‘lib, RMSE va MAEni pasaytirdi, shu bilan birga bo‘g‘liqlik ko‘rsatgichi (korrelyatsiya)ni 0,67 dan 0,87 gacha ko‘tarildi va shu bilan iqlim ma’lumotlarini aniqligi va muvofiqligi oshirildi.

3. Model simulyatsiyalari 2024-2053 yillarda SSP5-8.5 bo‘yicha suv mavjudligi taxminan 28.5% va SSP1-2.6 bo‘yicha 17.7% ga kamayishini prognoz qildi. Ushbu qisqartirishlar kelajakdagi suv resurslarida sezilarli cheklovlarni ko‘rsatadi, qishloq xo‘jaligi, sanoat va maishiy foydalanuvchilar o‘rtasida raqobatni kuchaytiradi.

4. Suv omborlari sathining mavsumiy tebranishlari SSP5-8,5 doirasida kuchayishi kutilmoqda, yozgi eng yuqori ko‘rsatgich avgust oyining oxiri-sentyabr oylarida 1060 m dan pastga tushishi mumkinligi aniqlangan. SSP1-2.6 ostida

tebranishlar kamroq jiddiy bo‘lib, yoz o‘rtalarida suv sathi 1070 m ga yaqin barqarorlashadi.

5. Tadqiqot shuni ta’kidlaydiki, iyun-iyul oylarida sug‘orishning eng yuqori talabini 10-15% ga mo‘tadillashtirish suv havzalarining muhim darajasini (masalan, 1065-1070 m dan yuqori) saqlashga yordam berishi mumkin. Ushbu chora yoz oxirida suv ta’minoti barqarorligini ta’minlaydi va jiddiy suv tanqislik xavfini kamaytiradi.

6. SSP5-8.5 bo‘yicha prognozlar uzoq davom etadigan qurg‘oqchilik va kuchli suv toshqini xavfi ortib borayotganini ta’kidlaydi. Yuqori aniqlikdagi gidrologik va meteorologik monitoring tizimlari suv toshqinlarini bashorat qilishni yaxshilash uchun zarur bo’lib, suv toshqinlari xavfini yumshatish uchun suv havzalaridan suv chiqarishni oldini olish va nazorat qilish imkonini beradi.

НАУЧНЫЙ СОВЕТ DSc.03/30.12.2019.T.10.02 ПО ПРИСУЖДЕНИЮ УЧЁНЫХ СТЕПЕНЕЙ ПРИ НАЦИОНАЛЬНОМ ИССЛЕДОВАТЕЛЬСКОМ УНИВЕРСИТЕТЕ «ТАШКЕНТСКИЙ ИНСТИТУТ ИНЖЕНЕРОВ ИРРИГАЦИИ И МЕХАНИЗАЦИИ СЕЛЬСКОГО ХОЗЯЙСТВА»

НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ УНИВЕРСИТЕТ «ТАШКЕНТСКИЙ ИНСТИТУТ ИНЖЕНЕРОВ ИРРИГАЦИИ И МЕХАНИЗАЦИИ СЕЛЬСКОГО ХОЗЯЙСТВА»

УЗБЕКОВ УМИДХОН УЛУГБЕК УГЛИ

ОЦЕНКА ВЛИЯНИЯ ИЗМЕНЕНИЯ КЛИМАТА НА ГИДРАВЛИЧЕСКИЙ И ГИДРОЛОГИЧЕСКИЙ РЕЖИМ ВОДОХРАНИЛИЩ

05.09.07-Гидравлика и инженерная гидрология

АВТОРЕФЕРАТ ДИССЕРТАЦИИ ДОКТОРА ФИЛОСОФИИ (PhD) ПО ТЕХНИЧЕСКИМ НАУКАМ

Ташкент – 2025

Тема диссертации доктора философии (PhD) по техническим наукам зарегистрирована в Высшей аттестационной комиссии при Министерстве высшего образования, науки и инноваций Республики Узбекистан за номером B2025.2.PhD/T148.

Диссертация выполнена в Национальном исследовательском университете “Ташкентский институт инженеров ирригации и механизации сельского хозяйства”

Автореферат диссертации на трех языках (узбекский, русский, английский (резюме)) размещен на веб-странице по адресу www.tiiame.uz) и на Информационно-образовательном портале «ZiyoNet» по адресу www.ziyonet.uz

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Защита диссертации состоится «____» _____ 2025 г. _____ часов на заседании Научного совета DSc.03/30.12.2019.T.10.02 при Национальном исследовательском университете «Ташкентский институт инженеров ирригации и механизации сельского хозяйства» по адресу: 100000, г.Ташкент, ул. Кары Ниязий, 39. Тел/Факс:. (+99871)-237-46-68, e-mail: admin@tiiame.uz.

С диссертацией (PhD) можно ознакомиться в Информационно-ресурсном центре Национального исследовательского университета «Ташкентский институт инженеров ирригации и механизации сельского хозяйства» (регистрационный номер ____). Адрес 100000, г. Ташкент, Кары Ниязий, 39. Тел. (+99871)-237-19-45, e-mail: admin@tiiame.uz

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ВВЕДЕНИЕ (аннотация докторской диссертации)

Цель исследования. Целью исследования является оценка влияния изменения климата на гидравлический и гидрологический режим водохранилищ.

Задачи исследования:

Аналитический анализ научных работ, проведенных для оценки влияния изменения климата на гидравлический и гидрологический режим водохранилищ;

Коррекция смещения и анализ данных климатической модели (Coupled Model Intercomparison Project 6 (CMIP6));

Оценка влияния изменения климата на гидравлический и гидрологический режим водохранилищ с использованием модели SWAT;

Разработка рекомендаций по оценке влияния изменения климата на водохранилище.

Область исследования. Гисоракское водохранилище, Шахрисабзский район, Кашкадарьинская область

Предметом исследования являются изменения характера осадков, повышение температуры и изменение режимов расхода воды, включая изменения расхода воды, уровней воды, скорости испарения и общего водного баланса.

Методы исследования. В исследовании использовались трендовый анализ существующих данных, коррекция смещения, калибровка и валидация данных климатической модели, а также гидравлическое и гидрологическое моделирование (с помощью модели SWAT).

Научная новизна исследования:

• Разработано программное обеспечение для повышения точности и коррекции смещения данных климатической модели с использованием алгоритмов машинного обучения;

• Прогностические данные сценариев глобального изменения климата CMIP6 (SSP1-2.6 и SSP5-8.5) впервые были адаптированы для бассейна реки Аксув с использованием метода коррекции статистического смещения;

• Разработаны климатические сценарии (SSP1-2.6 и SSP5-8.5) для оценки влияния изменения климата на гидравлический и гидрологический режимы водохранилища;

• Режим работы Хисоракского водохранилища разработан на основе усовершенствованной модели SWAT для различных периодов водности.

Практические результаты исследования

Разработана программа для исправления ошибок в данных климатической модели (коррекция смещения);

Разработана гидрологическая модель на языке программирования Python для оценки влияния изменения климата на водные ресурсы;

Усовершенствован метод оценки влияния изменения климата на гидравлический и гидрологический режим водохранилищ;

Надежность результатов исследования. Достоверность результатов исследований объясняется тем, что разработка теоретических решений базируется на общепринятых гидравлических законах и методах моделирования, полученные результаты практически анализируются с использованием статистических показателей, а результаты обладают высокой достоверностью и сопоставлены и проверены с данными, полученными другими учеными.

Научная и практическая значимость результатов исследований. Научная значимость результатов исследований заключается в том, что повышена точность анализа изменения климата в водохранилищах за счет разработки программного обеспечения для коррекции смещения данных климатической модели на языке программирования Python.

Также с учетом изменчивости климата улучшены параметры модели SWAT, необходимые для оценки влияния изменения климата на гидравлический и гидрологический режим водохранилищ.

Практическая значимость результатов исследований объясняется тем, что моделирование влияния изменения климата на гидравлический и гидрологический режим водохранилищ позволит более эффективно управлять водохранилищами за счет прогнозирования будущих расходов воды в водохранилищах, изменения уровней воды в водохранилищах, периодов высокого и низкого уровня воды.

Внедрение результатов исследований. В рамках исследования проведены модельные работы по оценке влияния изменения климата на гидравлический и гидрологический режим водохранилищ. При этом в основном использовались данные климатической модели для учета будущих изменений климата. По результатам:

Метод оценки влияния изменения климата на гидравлический и гидрологический режим водохранилищ принят к использованию на водохранилищах, находящихся в ведении Кашкадарьинского областного управления по использованию водохранилищ и Гисаракского водохранилища АО «Узбекэнерго». Применение результатов диссертационной работы в практике водохозяйственной деятельности позволит улучшить

гидрологический режим водохранилищ, повысить точность расчета элементов водного баланса, эффективно наполнять и опорожнять водохранилища, экономя более 10% водных ресурсов по сравнению с водой, которая тратится и забирается из источника.

Апробация результатов исследования. Результаты данного исследования обсуждались на 3 международных и 2 республиканских научно-практических конференциях.

Опубликование результатов исследования. 9 публикаций по диссертациям. 9 публикаций в научных изданиях, рекомендованных для публикации основных научных результатов докторских диссертаций Высшей аттестационной комиссией Республики Узбекистан, в том числе в 5 республиканских и 2 зарубежных журналах, получено 2 авторских свидетельства.

Структура и объем диссертации. Диссертация состоит из введения, четырех глав, заключения, списка литературы и приложений.

LIST OF PUBLISHED WORKS
E'LON QILINGAN ILMIY ISHLAR RO'YXATI
СПИСОК ОПУБЛИКОВАННЫХ РАБОТ

I part (I bo'lim, I часть)

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II part (II bo'lim, II часть)

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