CLIMATE CHANGE AND THE WATER RESOURCES OF THE AZERBAIJAN REPUBLIC

CHANGEMENT CLIMATIQUE ET RESSOURCES EN EAU DE LA REPUBLIQUE D'AZERBAÏDJAN

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ABSTRACT

Azerbaijan Republic has limited water resources, with river water resources of 30.9 km^3 of which, 10.3 km^3 is the country's share and the rest 20.6 km^3 are parts of transboundary rivers. The current total water abstraction is 12 km^3 annually and it exceeds the available river water resources. About 68% of the available water is used for irrigation. The two main factors responsible for gradual shortfall in the river water availability namely, climate change and development activities, have undergone conspicuous changes in the recent decades in Azerbaijan.

It is necessary and feasible to quantify such changes for future planning. Studies have indicated that the annual river flow to Aras has decreased by 63% and at Kura by 58% in comparison with the natural flow during the years 1996-2006. The phenomenon of climate change has drastically increased the frequency of extreme events (floods, mud flow, droughts etc.). Instance for devastating floods in the previous 100 years downstream of Kura had been just 2 times; however in the last 10 years such floods have already occurred 4 times (2003, 2006, 2007, 2010).

Estimation of the impact of climate change on water resources has been carried out for the years 1961-1990 years and it was used as a baseline for GISS and GFDL-3 scenarios. Interesting results obtained from the model PRECIS is that the difference of sum of precipitations and evaporation in the territory of Azerbaijan has significantly decreased. While precipitations increased by 20-80%, the increase in evaporation was higher. The net result was a decrease in the water supply in the territory by an average amount of

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0.2-0.5 mm/day. This is a big constraint to increase water allocation for irrigation to meet the increasing demand.

Key words: *Climate change, water resources, Azerbaijan Academy of Science, Kura River.*

RESUME

La République d'Azerbaïdjan possède la quantité limitée des ressources en eau. Sur le total des ressources en eau fluviales de 30,9 km^3, 10,3 km^3 d'eau fait partie du pays et le reste de 20,6 km^3 d'eau vient des rivières transfrontalières. L'abstraction totale actuelle annuelle est de 12 km^3 et ceci excède la limite des ressources en eau disponibles fluviales. Environ 68% de l'eau disponible est utilisée pour but d'irrigation. Le changement climatique et les activités de développement sont les deux facteurs principaux responsables du déficit graduel de la disponibilité de l'eau fluviale. Ces facteurs ont subi des changements remarquables au cours des décennies récentes à l'Azerbaïdjan.

Il est nécessaire et faisable d'évaluer de manière quantitative ces changements pour la planification future. Les études ont indiqué que le débit fluvial annuel à Aras a diminué de 63% et à Kura de 58% par rapport au débit naturel lors des années 1996-2006. Le phénomène de changement climatique a augmenté la fréquence d'événements extrêmes (inondations, sécheresses etc). Il y avait 2 cas d'inondation en aval de Kura au cours de 100 dernières années; cependant, il y avait 4 cas d'inondation dans les 10 dernières années (2003, 2006, 2007, 2010).

L'évaluation a été faite de l'impact du changement climatique sur les ressources en eau pendant les années 1961-1990. Le résultat obtenu a été utilisé comme une ligne de base pour les scénarios GISS et GFDL-3. Les résultats intéressants obtenus du modèle PRECIS ont montré que la différence entre la quantité de précipitations et de l'évaporation à l'Azerbaïdjan a diminué de manière significative. Les précipitations ont augmenté de 20-80%, mais l'augmentation de l'évaporation était plus haute. Le résultat net était une réduction de 0,2-0,5 mm/jours de l'approvisionnement en eau. Cela pose une grande contrainte à l'augmentation de l'allocation d'eau en irrigation pour satisfaire la demande croissante.

Mots clés: *Changement climatique, ressources en eau, Académie des Sciences d'Azerbaïdjan, rivière Kura.*

1. INTRODUCTION

Water resources of Azerbaijan are limited and demand for them is high. This article describes the current level of use of water resources and the expected situation in the future. This will be determined by the increased demand of water resources by different sectors and the expected reduction of water resources due to climate changes.

Azerbaijan Republic has limited water resources. The total river water resource is 30.9 km^3 of which the major portion of 20.6 km^3 is the share of other countries of the region, leaving only 10.3 km^3 of river flow for the Azerbaijan Republic. This amount is inadequate to meet even the current demand of 12 km^3 annually of which 68% is used for irrigation (Imanov 2009). Naturally, this is a major constraint for stabilizing and expanding agriculture in the republic. Besides, there are competing demands for water by the other sectors as well, which are also important and are expanding.

The currently alarming water scenario demands an urgent attention to the usage of water in the past few decades to chalk out the future programme of development. Thus, the dynamics of water consumption pattern during the past few decades due to multiple water users vis-à-vis the development efforts needs to be established. This will clarify the share of climate change and the development process in the currently felt water scarcity, will enable forecasting future needs of water and may indicate the possible measures to be undertaken to alleviate the water scarcity condition.

Some studies so far conducted in this regard have revealed that the annual river flows through Aras and Kura have reduced, respectively, by 63 and 58 per cent in comparison to the flows available during the decade from 1996-2006. On the effect of climate change, it has been found that the frequency of extreme hydro-meteorological events (floods, mud flow, droughts etc.) has drastically changed in the recent times. For example, the number of devastating floods in the previous 100 years at the downstream of Kura had been only 2, whereas in the last 10 years it had already occurred 4 times (2003, 2006, 2007, 2010).

2. ESTIMATION OF THE IMPACT OF CLIMATE CHANGE ON WATER RESOURCES

As Climate Change models the following scenarios have been used: GISS (Increase of annual air temperature by 4.8-5.3^{0}C and annual precipitation by 6 - 12%), GFDL-3 (Increase of annual air temperature by 4.2-4.4 ^{0}C and annual precipitation by 1 - 4%) and the climate change models and scenario recommended by specialists of Azerbaijan Academy of Science (air temperature increase by 2 ^{0}C: Verdiyev 2009).

Taking into account changes of air temperature and precipitation in accordance with climate change scenarios based on amounts of the available for today at the territory of Azerbaijan (observed) annual run-off of Kura and potential water resources of the it (Natural run off amounts) the climate change impact to the water resources of Kura has been estimated (Table 1).

As is seen from Table 1, decrease of water resources of the river may be between 10 and 20% in the future, as predicted by all the models, if there are no measures adopted to address the apprehended scenario.

Table 1. Change of water discharges of Kura River under climate change models.

Run–off ranges	Water discharges , m^3 /sec				
	Winter	Spring	Summer	Autumn	Annual
	XII-II	III-V	VI-VIII	IX-XI	XII-XI
Initial scenario (1961-1990)					
Natural	403	1528	897	524	840
Percent of seasonal values of natural run-off from their annual sum	12.1	45.8	26.8	15.6	100
Observed	334	1233	684	400	663
Percent of seasonal values of observed run-off from their annual sum	12.6	46.5	25.8	15.1	100
$\Delta t = 2\ ^0C$, $\Delta R = 0$ % (scenario supposed by the Azerbaijan Academy of Science)					
Natural	398	1391	766	460	755
Percent of seasonal values of observed run-off from their annual sum	13.2	46.0	25.3	15.1	100
Observed	306	1075	592	354	583
Percent of seasonal values of observed run-off from their annual sum	13.1	46.1	25.3	15.1	100
GISS					
Natural	357	1273	756	412	698
Percent of seasonal values of natural run-off from their annual sum	12.8	45.0	27.1	14.8	100
Observed	255	966	574	312	527
Percent of seasonal values of observed run-off from their annual sum	12.8	45.3	27	14.7	100
GFDL-3					
Natural	341	1319	682	390	682
Percent of seasonal values of natural run-off from their annual sum	12..5	48.5	25.0	14.3	100
Observed	272	1081	437	291	520
Percent of seasonal values of observed run-off from their annual sum	13.1	52	21	14	100

The results of the studies also reveal a reduction in the annual and seasonal amounts of ecological flow (the minimal monthly run-off necessary for existence of river ecosystem) of Kura river by all the three of given climate change models under the condition of a rise in the air temperature (Table 2).

It is revealed that atmosphere precipitation increase prevents run-off to reduce except relative amounts of winter run-off.

Table 2. Ecological run-off (m^3/sec.) of Kura River near mouth under climate change

River-Station	Monthly ecological run-off, m^3/sec.												Annual
	1	2	3	4	5	6	7	8	9	10	11	12	
Kura-Salyan Actual (Observed)	286	298	366	645	760	547	218	147	197	238	273	280	**354**
Kura-Salyan by GISS	268	275	311	544	660	426	201	120	137	199	248	267	**305**
Kura- Salyan by GFDL-3	252	263	295	520	624	406	161	91	125	191	228	254	**284**

3. CLIMATE PREDICTION FOR AZERBAIJAN

Taking into account the Global Circular Models recommendations (GCM) of the IPCC and the proposal of Hadley Centre, and after negotiations among the countries of region (Turkey, Georgia, Azerbaijan and Armenia), it was resolved that the emission scenarios are to be estimated using the PRECIS model for Azerbaijan.

The facts of ECHAM4 for 1960-2100 years on A2 scenario from Global Circular Model ocean-atmosphere of Macs Plank Institute was chosen as border conditions. The calculations were done for three periods as indicated below:

- The first period 1960-1990 play the role of base climate
- The second period, the period of scenario: 2020-2050
- The third period also the period of scenario is 2070-2100

In the calculation, made for the first time in Azerbaijan Republic, the data used characterize the past and future climates. Analyses of data were carried out by special systems of visualization (XCONV, VCDAT, IDT, GRADS and other).

According to the Special Report on Emission Scenarios of IPCC, the emission scenarios accepted are: AIFI, A2, B2 and B1. The emission scenario is determined in relation to the development in demography, economy, technology, energy and agriculture (Fig.1). In accordance with emission scenarios with CO_2 the global temperature will increase approximately by 2 to 5 degrees Celsius.

The previous research illustrated that geographical situation of Azerbaijan is such that the rise in average temperature will be equal to the global values.

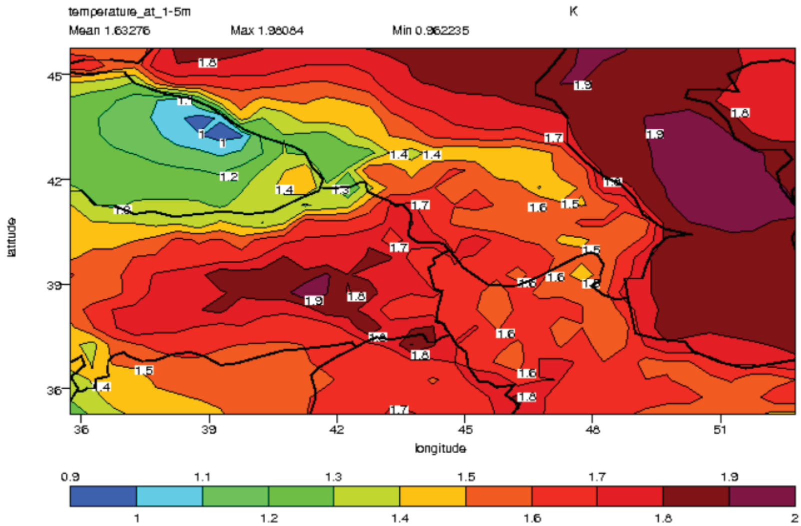

Fig. 1. The growth of mean annual temperature in region (2021-2050 and 1961-1990: PRECIS, Emission Scenario; SRES-A2, without sulfates, Boundary conditions: ECHAM4).

3.1. Climate 1961-1990 base period and control of model

The test of model was done on the base of results of 1961-1190. In this period the distribution of temperature in the region was correctly estimated by model. In Tallish mountains; in high mountain territories and in the steppe territories the model-predicted temperatures were close to the actual observations. However, in some territories the model predicted temperatures higher than the observed values. The model verification was done in accordance with the recommendations of Hadley Centre (Climate Research Unit,//www.cru.uea.ac.uk./cru/data).

The difference between the model-predicted and observed temperatures in the Azerbaijan republic in particular and in the Caucasus region in general, varied in the range from - 0.5^{0}C to + 0.5^{0}C; with the feature that within the boundary of the Azerbaijan Republic, the predicted temperatures were higher than the observed values. This difference in east coasts of Caspian Sea was more and reached 3 – 4 degrees Celsius. In east regions of the Republic; in Absheron, Central steppe regions and in Qazakh – Ganja zone, the difference was +1.5^{0}C. In other territories of the Republic this difference was 0.5^{0}C. During drawing up of climatic scenario these differences are considered (Khalilov 2009).

The distribution of precipitations was by and large well reflected by the model. The least precipitations are observed in Absheron-Qobustan and Nakhichivan AR. In mountain and foothills regions the precipitations are higher. In Lenkeran-Astara zone and in south slopes of Great Caucasus there are high precipitations. The quantity indexes of precipitations also agreed with climatic data. For example, in Absheron-Qobustan the precipitation is approximately 300 mm, in steppe regions it is between 300-600 mm. In south slope of Great Caucasus the precipitations are higher and of the order of 1500-1800 mm.

In the territory of Tallish the precipitation is very little, except the precipitations in the Lenkeran-Astara zone. The distribution of precipitations in other territories is more real.

In the various territories of the Republic the difference between model indexes and facts of CRU were close to zero. However, there is a great difference between model indexes and climatic data in Great Caucasus and Lenkeran-Astara zone; the difference in Lenkeran-Astara zone is due to the fact that the precipitation data of this region is not considered among the various data of CRU. In Great Caucasus the difference was due to an error in the modeling.

3.2. Climatic scenario during 2020-2050

According to the PRECIS's model and vis-à-vis the border conditions and emission scenario during 2021-2050, the rise in temperature would be 1.5 - 1.6^{0}C (Fig.1). In riparian territories and west regions of Nakhichivan AR the increase reaches 1.7^{0}C. In the first half of the current century, the rise in temperature may be 0.3^{0}C per decade, on the average. The actual rise in temperature during 1900-2000 in the Republic was approximately 0.4^{0}C; and this shows that the model reflects the climatic changes in region.

Based on the 1961-1990 pattern, the precipitations increase in the Azerbaijan Republic during 2020-2050 may be 10-20%. At the same time in west regions of Nakhichivan AR the increase may be 0-10% but in east regions, the increase ie likely to be 20%. As we see from Fig. 2, precipitation had not decreased in the Kura-Araz basin.

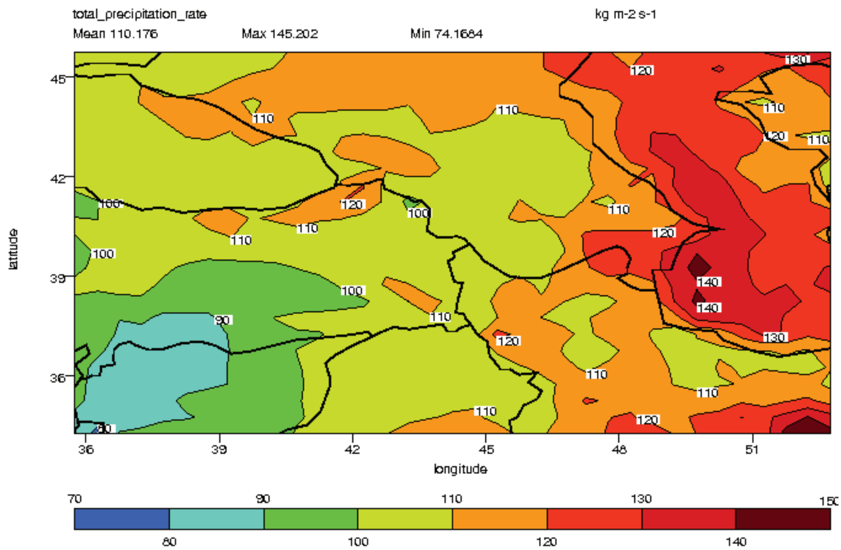

Fig. 2. The variability of precipitations, % (2021-2050 in comparison with 1961-1990).

In accordance to the anticipated scenario, the difference of sum of precipitation and evaporation during 2021 – 2050 in comparison with basis period of 1961 – 1990 may be in the range of 0.4 - 1.2 mm/day for the whole Kura-Araz basin. In this period the water supply is likely to increase. In comparing the last with the other scenarios we can accept this as a positive factor. By the end of century, however, this trend of factor is likely to be reversed, i.e., increase till 2050 and then decreases (Fig.3). The increase in evaporation happens with greater speed.

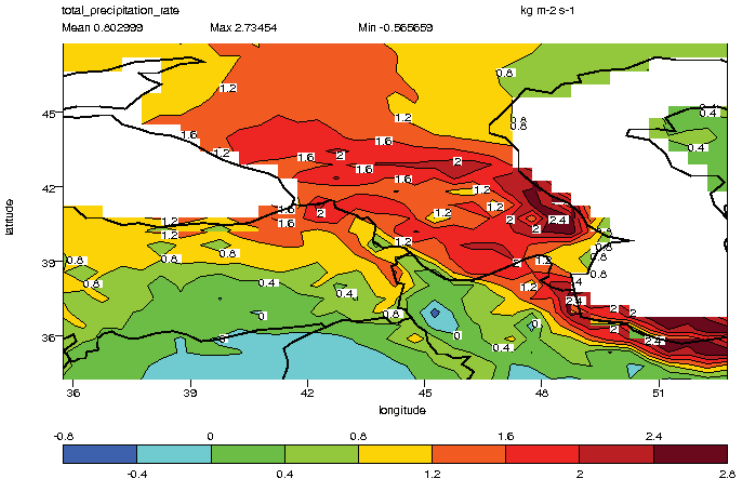

Fig. 3. The change in the difference sum of evaporation and precipitation (mm/days) in period of scenario in comparison with basis period (1961-1990 and 2021-2050, PRECIS, Emission Scenario: SRES-A2, without sulfates, Boundary conditions: ECHAM4).

3.3. Climatic scenario 2070 - 2100

The temperatures estimatedby PRECIS model for 2071-2100 in comparison with the base year (1961-1990) shows an increase by 3 - 6^{0}C. In Nakhichivan AR this growth is 5.4 - 5.7^{0}C (Fig.4). The maximum temperature rise may be 2 - 7^{0}C. Hence the present time maximum temperatures of 44 - 46^{0}C may become 47 - 53^{0}C.

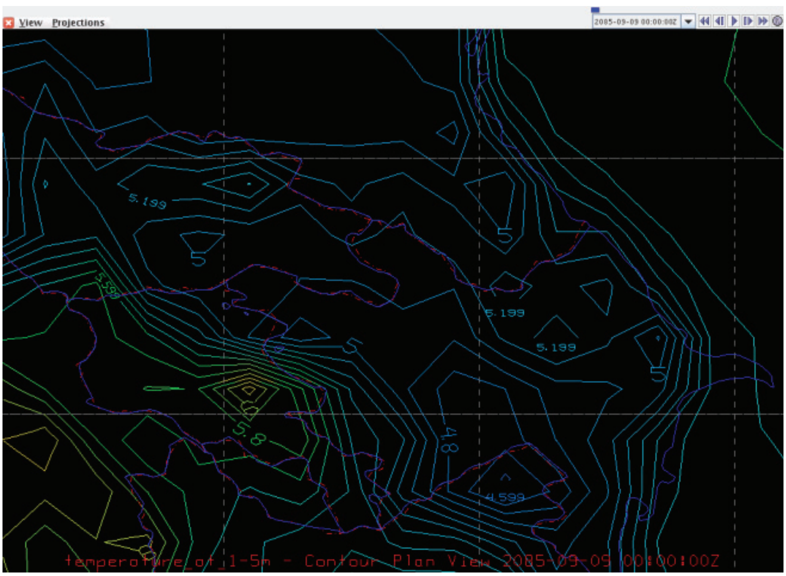

Fig. 4. Increase in the mean annual temperature in region (difference between 2071-2100 and 1961-1990: PRECIS's; Emission Scenario: SRES-A2, without sulfates, Boundary conditions: ECHAM4).

There is precipitations increase from west to east by 20 to 80 per cent in the Republic. Only In Nakhichevan AR it may decrease by 20% (Fig.5).

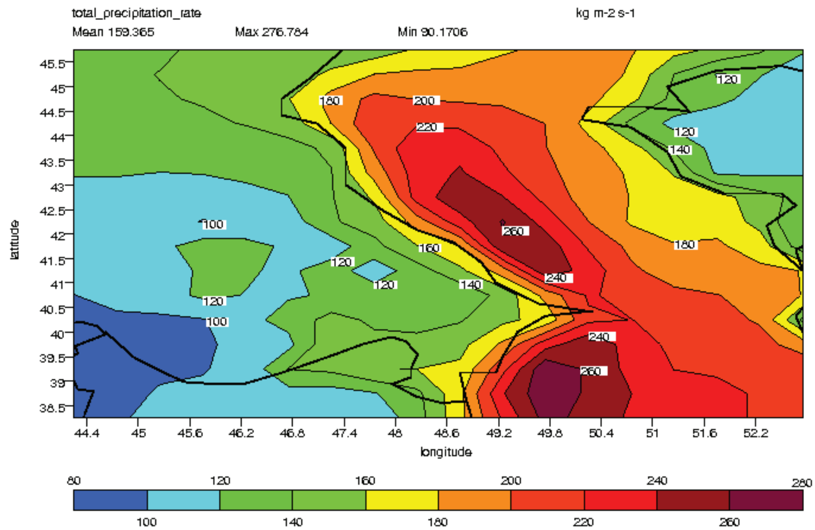

Fig. 5. The variability of precipitations, % (2071-2100 in comparison with 1961-1990 PRECIS, Emission Scenario: SRES-A2, without sulfates, Boundary conditions: ECHAM4).

The large increase in precipitations in the Caspian Sea and the surrounding regions creates doubt about adequacy of the model in predicting the future precipitation scenario. Therefore, considering other parameters in the model to improve its performance may be needed in the future to improve the forecast.

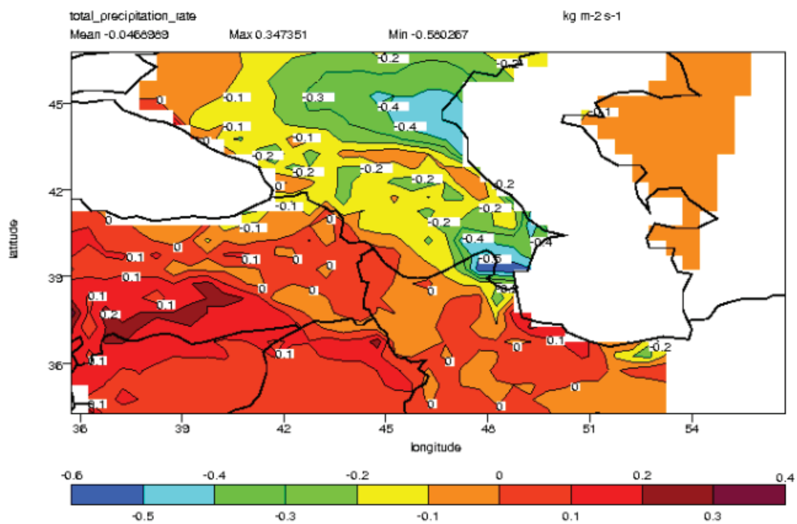

Fig. 6. The variability of sum of precipitation and evaporation (mm/days) in the region (1961-1990 and 2071-2100, PRECIS, Emission Scenario: SRES-A2, without sulfates, Boundary conditions: ECHAM4).

The article presents an assessment of the role of Climate change, economy development and population increase on the availability of water resources in the Azerbaijan Republic.

Based on results, the total amount of annual water abstraction (12 km^3) now exceeds the water resources available to the country. Analysis of changes occurring in the dynamics of water consumption, impact of other types of economic activities and forecasts of development of economy and population, besides climate change has been carried out to assess the perspective of water availability and load on water resources in various regions of Azerbaijan.

Taking into account the already witnessed effects of climate changes (drastic increase in the frequency of extreme hydro-meteorological events such as floods, mud flow, droughts, rise of air temperature , increase of evaporation etc.) it was predicted that in total water resources demand will be increased under different climate change scenarios and their availability will be decreased.

4. CONCLUSIONS

Based on the study, the following conclusions are drawn:

Water resources of Azerbaijan are limited and demand for them is high. The current water withdrawal exceeds the fresh water available by about 1.7 km^3 annually. This gap is likely to increase due to various development activities.

It was found that the annual flow is decreased by 63% in Aras and by 58% in Kura, in comparison to the situation prevailing during 1996-2006.

Estimation of climate changing's impacts to water resources is carried out for 1961-1990 and it was used as a base for further modeling work for GISS and GFDL-3 scenarios.

The study using the PRECIS model revealed that despite an increase in the annual precipitation, the difference between precipitation and evaporation had narrowed due to a greater increase in evaporation.

Taking into account the change in climate in the future, it was predicted that the total water resources demand will be increased under different climate change scenarios and their availability will be decreased.

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