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# TEMPERATURE AND PRECIPITATION PROJECTIONS UNDER AR4 SCENARIOS: THE CASE OF KUCUK MENDERES BASIN, TURKEY

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**Abstract**. In the study, downscaling models based on artificial neural networks were established for monthly average and maximum temperature and monthly total precipitation projections of Seferihisar, Selcuk and Odemis meteorological stations in the basin. In the models, NCEP/NCAR re-analysis variables were used as predictors. The downscaling models calibrated with the optimum predictors convert the coarse resolution results of both reference period (20C3M; 1981–2010) and future period (A2, A1B and B1; 2021–2100) scenarios of ECHAM5 climate model to the station scale temperature and rainfall forecasts. Corrections of biases in the forecasts are achieved by using cumulative distribution functions. According to the A2, A1B and B1 scenarios, the mean of monthly average temperatures of 2021–2100 period could increase by 3.2, 3.5 and 2.8°C, respectively and the mean of monthly maximum temperatures of 2021–2100 period could increase by 1.6, 2.1 and 1.1°C, respectively, the mean of annual total precipitation could decrease by 31.6, 42.9 and 30.2%, respectively over study region. Under these possible impacts, it is expected that the average net irrigation water demand and soil salinity will increase, water supply will decrease. Under these stressed conditions, it has to be changed cropping pattern of the basin.

*Keywords*: AR4 projections, downscaling, Kucuk Menderes Basin.

## AIMS AND BACKGROUND

In the study, it was aimed to prepare temperature and precipitation projections under different climate change scenarios and to present predictions on the possible effects of these possible temperature and precipitation changes on the agricultural activities in the Kucuk Menderes Basin. It is predicted that there will be significant changes in meteorological variables in regions where Mediterranean climate is dominant under climate change will have significant effects on temperature and precipitation in particular. The effects of climate change studies from an agricultural point of view can be found in the literature for Turkey[1–8].

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EXPERIMENTAL

*Study area*. The study area covers the Kucuk Menders Basin in Turkey, which is located between Gediz Basin and Buyuk Menderes Basin in the Aegean Region and flowing into the Aegean Sea (Fig. 1). The precipitation area of the Basin is 6907 $km^2$.

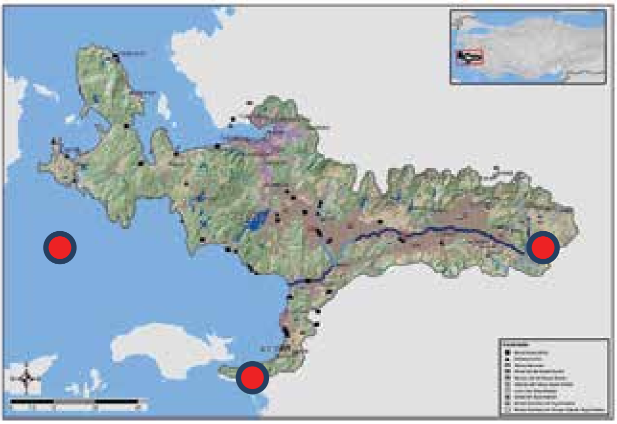

**Fig. 1**. Kucuk Menderes Basin[1]

The region area covers of nearly 39% agricultural areas, grape, maize, cotton, citrus and various vegetables are the main crops grown in the basin.

*Meteorological data*. The monthly average and maximum temperature and precipitation data were obtained from Odemis, Seferihisar and Selcuk meteorological stations located in the basin for the period January 1981 to 2010. The mean annual temperatures were 16.7, 16.9 and 16.7°C, the maximum temperatures were 23.9, 22.3 and 23.5°C, the total annual precipitations were about 549, 613 and 654 mm, respectively for the same period. Maximum temperatures are observed in July and the great majority of precipitations is observed generally in the winter, whereas summer is much drier.

The observed monthly average and maximum temperatures and precipitation were used for the statistical downscaling exercise and provided from the Turkish State Meteorological Service (MGM). These data of each station from January 1981 to December 2010 were considered as the predictand, whereas NCEP/NCAR (National Centres for Environmental Prediction/National Centre for Atmospheric Research) monthly reanalysis data were selected as potential predictor variables for the observation period. The dataset consists of mean air temperature (air), geopotential height (hgt) and relative humidity (rhum) at different atmospheric levels (200, 500 and 850 hPa), large-scale precipitation (pr) and sea-level pressure (slp) at Earth surface, which are the probable predictor variables which were common to data involved in ECHAM5.

*Climate model*. The large-scale output databases from ECHAM5, which include both historical scenario outputs representing past climates and future climate simulations under the A2, A1B, and B1 scenarios, $CO_2$ gas concentrations are equivalent to 850, 720 and 550 parts per million for the year 2100 respectively in, were selected for the downscaling application based on ANN techniques to transform ECHAM5 outputs to the monthly average and maximum temperature and precipitation for each station.

*Method*. The All possible regression method (APREG), assessment of subset regression combinations can be based the root mean squared error (RMSE) and Mallows Cp co-efficient. Details about the APREG procedure applied to downscaling studies are given in Ref. 9. The subset regression model with the lowest RMSE and Cp should be chosen as the best one. The predictor selection process determined the model with only large-scale 'air' for the downscaling of monthly average temperature and maximum temperature, large-scale 'pr' and 'air850' is sufficient for the downscaling of monthly precipitation for each meteorological stations.

Downscaling models based on artificial neural networks (ANNs) can be defined as a black box technique producing output against input(s) and is one of the preferred statistical downscaling techniques. Levenberg–Marquardt algorithm (LM) was used composed of feed forward and back propagation steps. It is a second-order optimisation algorithm and generally faster and more suitable than others[10].

Nash–Sutcliffe efficiency (NS), root mean squared error-observations standard deviation ratio (RSR) and bias percentage (PBIAS) were used to examine predicting capabilities of statistical downscaling models. Detailed information of these metrics and ratings pertaining to metrics are given in Ref. 11.

After downscaling of the temperatures and precipitations, bias correction methods based on cumulative distribution functions (CDFs) applied to raw ECHAM5 outputs both past future scenarios. Firstly, cumulative distribution functions (CDFs) of downscaled past scenario results are mapped onto the CDFs of observations. After that, corresponding to the downscaled values for future periods, the CDFs are computed from the CDFs relating to the past scenario results. Finally, the corrected values of a variable for future periods can be extracted from the CDFs of the observations[12].

The whole method used in this study is given in more details in Ref. 6.

## RESULTS AND DISCUSSION

The subset regression model with the lowest RMSE and Cp should be chosen as the best one. However, it was determined that 'air', 'air' and 'prate and air 850' were enough for estimating of the monthly mean temperature, maximum temperature and monthly total precipitation, respectively according to performance criteria. Performance values for testing period of the ANN model established for the Odemis stations are presented in Table 1.

As shown in Table 1, the performance of the ANN models, which were established with 'air' variables for the monthly average temperature and the maximum temperature, was very good according to three performance criteria. The performance of the ANN model, which was established with 'prate and air 850' variables for the total monthly precipitation, was very good also according to three performance criteria for the Odemis station.

Downscaled and bias corrected results of A2, A1B and B1 scenario of the ECHAM5 for the meteorological stations is given in Tables 2–4 and Figs 2–4.

**Table 1**. Results of performance criteria for Odemis ANN model testing period

| Predictor | | RMSE (°C) | $R^2$ (–) | Adj. $R^2$ (–) | NS (–) | RSR (–) | PBIAS (%) | Min. (°C) | Max. (°C) | Mean (°C) | Std. dev. (°C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean monthly temperature | observed | – | – | – | – | – | – | 5.00 | 30.80 | 17.19 | 7.56 |
| | model | 1.11 | 0.98 | 0.98 | 0.98 | 0.15 | 1.60 | 4.18 | 31.18 | 16.91 | 7.37 |
| Maximum temperature | observed | – | – | – | – | – | – | 9.00 | 39.05 | 24.30 | 8.71 |
| | model | 1.26 | 0.98 | 0.98 | 0.98 | 0.14 | 0.45 | 9.62 | 37.73 | 24.19 | 8.32 |
| Total monthly precipitation | observed | – | – | – | – | – | – | 0.00 | 227.40 | 47.72 | 50.48 |
| | model | 24.16 | 0.77 | 0.77 | 0.77 | 0.48 | 3.86 | –4.10 | 193.88 | 45.88 | 44.23 |

**Table 2**. Mean monthly temperature projections under different scenarios

| Time period | Annual mean temperature (°C) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Odemis | | | Seferihisar | | | Selcuk | | |
| | A2 | A1B | B1 | A2 | A1B | B1 | A2 | A1B | B1 |
| 2021–2030 | 16.9 | 18.1 | 18.2 | 17.1 | 18.3 | 18.4 | 16.9 | 18.1 | 18.2 |
| 2031–2040 | 17.8 | 18.5 | 18.0 | 18.1 | 18.7 | 18.2 | 17.8 | 18.5 | 18.0 |
| 2041–2050 | 18.9 | 19.2 | 19.0 | 19.1 | 19.4 | 19.2 | 18.9 | 19.3 | 19.1 |
| 2051–2060 | 19.5 | 19.9 | 19.1 | 19.7 | 20.2 | 19.3 | 19.6 | 20.0 | 19.1 |
| 2061–2070 | 20.4 | 20.7 | 19.4 | 20.7 | 20.9 | 19.7 | 20.5 | 20.8 | 19.5 |
| 2071–2080 | 21.2 | 20.8 | 20.4 | 21.3 | 21.0 | 20.6 | 21.2 | 20.9 | 20.4 |
| 2081–2090 | 22.1 | 21.9 | 20.6 | 22.4 | 22.5 | 20.8 | 22.4 | 22.4 | 20.6 |
| 2091–2100 | 22.3 | 21.8 | 21.0 | 22.7 | 22.1 | 21.3 | 22.6 | 22.0 | 21.1 |

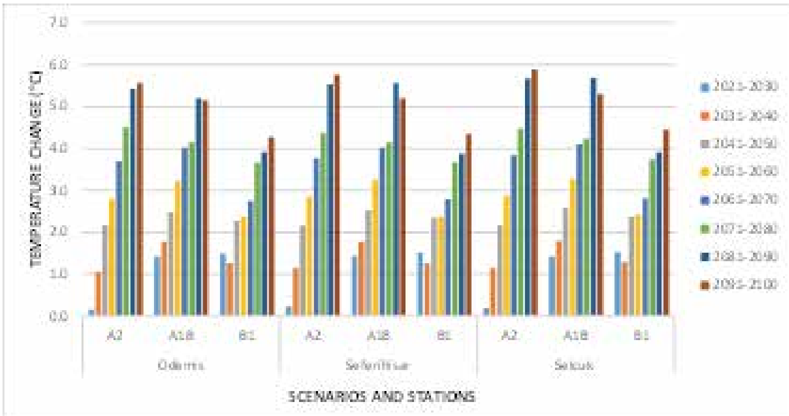


**Fig. 2**. Change of annual mean temperature projections under different scenarios

According to the A2, A1B and B1 scenarios, the annual monthly temperatures of 2021–2100 period will increase by 3.2, 3.4 and 2.7°C at Odemis, 3.2, 3.5 and 2.8°C at Seferihisar and 3.3, 3.6 and 2.8°C at Selcuk, respectively. These increases will range from 5.9°C for A2 to 4.3°C for B1 at the end of the century. This situation causes to change the plant growth periods not only duration but also starting and ending days. Shortening of growing periods can cause secondary crops to be cultivated. This may lead to an increase in total water consumption as well as an increase in total production. However, shorter growing period causes lower yield when compared to previous conditions.

**Table 3**. Maximum temperature projections under different scenarios

| Time period | Maximum temperature (°C) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Odemis | | | Seferihisar | | | Selcuk | | |
| | A2 | A1B | B1 | A2 | A1B | B1 | A2 | A1B | B1 |
| 2021–2030 | 36.6 | 38.4 | 38.5 | 33.7 | 35.5 | 35.5 | 34.9 | 37.3 | 37.4 |
| 2031–2040 | 38.0 | 38.9 | 38.0 | 35.0 | 35.8 | 34.8 | 36.2 | 38.0 | 36.5 |
| 2041–2050 | 39.8 | 39.6 | 39.4 | 36.7 | 36.6 | 36.3 | 39.3 | 38.9 | 38.2 |
| 2051–2060 | 39.8 | 41.1 | 40.0 | 36.7 | 37.6 | 36.5 | 38.9 | 40.2 | 39.0 |
| 2061–2070 | 41.6 | 41.4 | 39.8 | 38.2 | 37.6 | 36.8 | 40.8 | 41.3 | 38.6 |
| 2071–2080 | 41.6 | 41.7 | 40.5 | 38.3 | 38.2 | 37.3 | 42.3 | 40.8 | 39.9 |
| 2081–2090 | 43.9 | 45.2 | 42.7 | 39.3 | 40.1 | 39.0 | 42.4 | 40.5 | 41.9 |
| 2091–2100 | 44.5 | 44.0 | 41.2 | 39.9 | 39.7 | 38.1 | 41.4 | 42.5 | 41.4 |

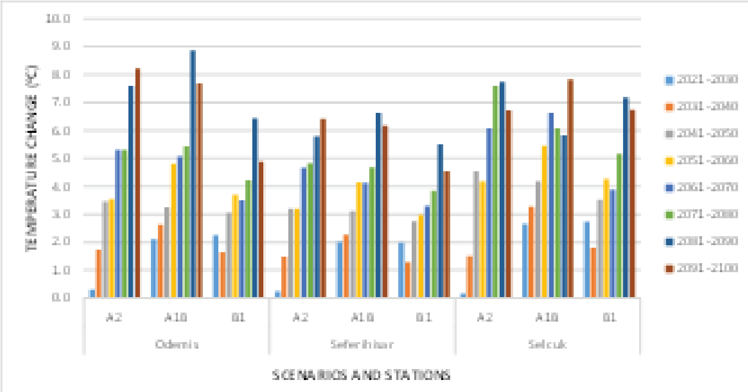


**Fig. 3**. Change of maximum temperature projections under different scenarios

According to the A2, A1B and B1 scenarios, the maximum temperatures of 2021–2100 period will increase by 4.4, 5.0 and 3.7°C at Odemis, 3.7, 4.1 and 3.3°C at Seferihisar and 4.8, 5.2 and 4.4°C at Selcuk, respectively. These increases will range from 8.2°C for A2 to 4.6°C for B1 at the end of the century. Under this situation, it is expected that some of the crops produced in the basin can not be grown due to the heat stress conditions.

**Table 4**. Annual total precipitation projections under different scenarios

| Time period | Annual total precipitation (mm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Odemis | | | Seferihisar | | | Selcuk | | |
| | A2 | A1B | B1 | A2 | A1B | B1 | A2 | A1B | B1 |
| 2021–2030 | 580 | 382 | 400 | 678 | 407 | 464 | 740 | 416 | 510 |
| 2031–2040 | 421 | 389 | 470 | 465 | 441 | 528 | 503 | 462 | 570 |
| 2041–2050 | 449 | 393 | 431 | 482 | 413 | 485 | 531 | 423 | 525 |
| 2051–2060 | 346 | 323 | 427 | 372 | 371 | 476 | 411 | 398 | 507 |
| 2061–2070 | 326 | 287 | 367 | 350 | 312 | 417 | 389 | 316 | 438 |
| 2071–2080 | 367 | 341 | 298 | 388 | 373 | 334 | 432 | 397 | 346 |
| 2081–2090 | 295 | 219 | 335 | 321 | 230 | 367 | 332 | 236 | 398 |
| 2091–2100 | 238 | 239 | 316 | 267 | 269 | 357 | 257 | 260 | 380 |

In Fig. 4, positive numbers mean decreasing rate as percentage by 20C3M historical period of ECHAM5. Increasing was calculated only at Odemis in the 2021–2030 period as 5.7%. According to the A2, A1B and B1 scenarios, the annual total precipitation of 2021–2100 period will decrease by 31.2, 41.4 and 30.7% at Odemis, 38.5, 47.6 and 38.0% at Seferihisar and 42.2, 52.8 and 41.8% at Selcuk, respectively. These increases will range from 63.5% for A2 to 42.4% for B1 at the end of the century. Decrease in precipitation with increasing temperature leads to increase average net irrigation water demand and soil salinity because the salts that accumulate in the soil during the growing period can not be leaching effectively by precipitation. This can be solved by using pressurised irrigation systems, the good irrigation and cultivation planning.

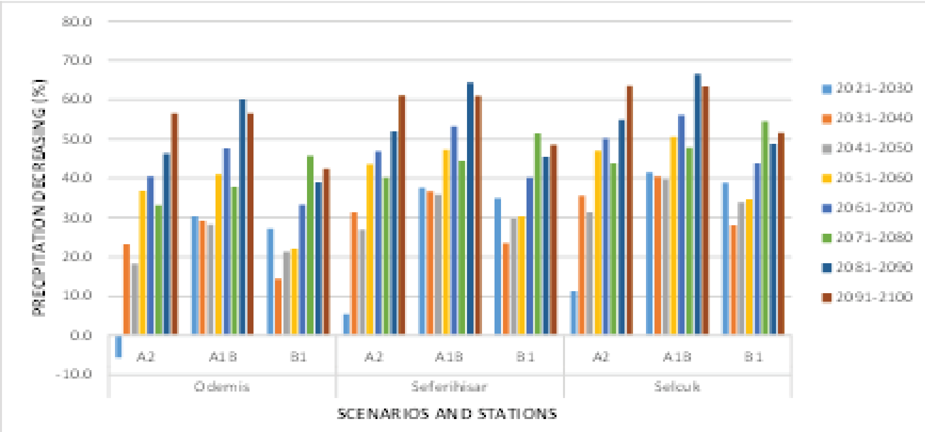


**Fig. 4**. Relative change of annual total precipitation projections under different scenarios

## CONCLUSIONS

The analysis of climate change effect on temperature and precipitation is very important for the reliability of agricultural production, water management and environmental sustainability. In this study, downscaling models based on artificial neural networks were established for mean monthly average and maximum temperature and annual total precipitation projections of Seferihisar, Selcuk and Odemis meteorological stations to present predictions on the possible effects of agricultural production in the Kucuk Menderes Basin.

It is expected that as mean and maximum temperature increase the average net irrigation water demand will increase, soil salinity will increase because the salts that accumulate in the soil during the growing period can not be leaching effectively by precipitation, some of the crops produced in the basin will inappropriate due to the stress conditions, such as higher mean and maximum temperature, decrease water supply and saline soil condition, it has to be change cropping pattern of the basin. Some of the crops has to be cultivate in a greenhouse and livestock can be preferred rather than the production of some crops. Beside of these, increasing temperature will have a direct impact on the diseases, pest and its types and populations. This may lead to decrease agricultural production, increase use of pesticides and cause increase of the environmental pollution. Groundwater consumption will increase because of decreasing the surface water resources. This will cause a decrease water level in well and increase salinity of the groundwater by seawater interference. Decrease of precipitation may lead to change of the ecological dynamics of basins ecosystems as it will reduce the amount of water left to flow for the needs of other species.

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