RISCURI ŞI CATASTROFE, NR. XIII, VOL. 15, NR. 2/2014

ASSESSMENT OF THE POTENTIAL IMPACT OF CLIMATE CHANGE UPON SURFACE WATER RESOURCES IN THE PRAHOVA RIVER BASIN

M. RETEGAN[1]

ABSTRACT. Assessment of the potential impact of climate change upon surface water resources in the Prahova river basin. The aim of the present research is the determination of the impact of possible climatic changes in the 21st century upon surface water resources in the Prahova river basin using the WatBal model (a mathematical-hydrological water-balance model).

The analyzed river basin covers an area of 3682 km² and is located outside the curvature of the Carpathian Mountains, in an area where the altitude varies between 60 m and 2500 m. In accordance with the altitude, the annual precipitation varies from approximately 550 mm/year in the plain area to over 1000 mm/year in the mountain area and the evaporation-transpiration between 850 mm/year in the plain area to 500 mm/year in the high areas. On the other hand, due to a very high variability of weather conditions, droughts, as well as excessive humidity periods, may occur during the year.

WatBal is an integrated water balance model developed for assessing the impact of climate changes on a river basin runoff.

This model has essentially two main modelling components. The first is the water balance component that uses continuous functions to describe water movement into and out of a conceptualized basin. The second component is the computation of the potential evaporation-transpiration processes.

Monthly data series recorded at 5 weather stations and 1 runoff gauging-station during the 1961-2007 period have been used for the calibration of the WatBal model to the local conditions of the area.

Finally, the paper focuses on the values of the mean monthly discharges at Adâncata river station on the Prahova River, estimated in the above-mentioned hypotheses. The paper analyses the influence of potential climatic changes, expressed by a wide range of climatic scenarios, upon the average water resources in the Prahova river basin.

It has also been taken into consideration the below average water resources, expressed by the minimum-monthly average flow and characteristic to low-water periods as well as the above average water resources, expressed by the maximum monthly average flow and characteristic to high-water periods.

Key-words: Prahova River Basin, climate changes, WatBal model, surface water resources.

[1] National Institute of Hydrology and Water Management, mihai_rete@yahoo.com

1. Introduction

In order to estimate the impact that the climate changes have upon the water resources in a specific river basin we can use a water-balance type of model that shows very good results when used within a monthly time-scale context (the WatBal Model).

The model works with two sets of climatic scenarios: the present climatic regime (scenario type 0) that estimates the liquid run-off related to the present, already observed, climatic conditions and a modified climatic regime (a group of scenarios labelled with the indicative 1) in which the model estimates the liquid run-off related to specific, hypothetical, climatic conditions.

In order to estimate the impact of climate changes upon the water resources in the Prahova River Basin we have used the two types of climatic scenarios mentioned above:

- Type 0, also known as the basic climatic conditions scenario, which evaluates the characteristics of the monthly average liquid run-off in the Prahova River Basin related to the climatic parameters that have already been observed at the weather stations during the 1961-2007 interval (tab.1).

- Type 1, also referred to as the modified climatic conditions scenarios, which estimates the parameters of the monthly average run-off related to changed climatic parameters, under various hypotheses (tab. 1). In these hypothetical situations the model operates with the already recorded average monthly discharges from the gauge station for which it is applied, but the climatic parameters that are taken into consideration (air temperature and amount of rainfall) are changed according to each climatic scenario (tab.1). Thus, the model simulates new monthly average discharges which are different from the recorded ones, may be higher or lower and also their amplitude may be more or less significant.

Table 1. The climatic scenarios used with the WatBal model in the Prahova River Basin at Adâncata River Station

*T+0°C; **P+0% ***(Scenario 0 – Basic Climatic Conditions)***	T+0°C; P+10% ***(Scenario 1.1)***	T+0°C; P+20% ***(scenario 1.2)***	T+0°C; P-10% ***(scenario 1.3)***	T+0°C; P-20% ***(scenario 1.4)***
T+2°C; P+0% ***(scenario 1.5)***	T+2°C; P+10% ***(scenario 1.6)***	T+2°C; P+20% ***(scenario 1.7)***	T+2°C; P-10% ***(scenario 1.8)***	T+2°C; P-20% ***(scenario 1.9)***
T+4°C; P+0% ***(scenario 1.10)***	T+4°C; P+10% ***(scenario 1.11)***	T+4°C; P+20% ***(scenario 1.12)***	T+4°C; P-10% ***(scenario 1.13)***	T+4°C; P-20% ***(scenario 1.14)***

*T – average monthly uniform air temperature for the entire area of the Prahova River Basin;
**P – monthly amount of rainfall uniformly distributed over the entire area of the Prahova River Basin.

2. Data and Methodology

Adâncata is the last hydrometric station on the Prahova River, controlling the entire liquid run-off of the Prahova River Basin. It is located approximately 5 km upstream the confluence of the Prahova and the Ialomița Rivers and has an area of the corresponding basin of 3682 km^2.

In order to estimate the potential impact of climate changes upon surface water resources in the Prahova river basin there have been used two categories of data to apply the WatBal model.

The first category refers to the two main climatic parameters that the model works with, air temperature and amount of rainfall, while the second category refers to the hydrological element which expresses the mean liquid run-off on a river, more specifically the monthly average liquid discharges.

The climatic data used in the model are represented by the mean monthly air temperatures recorded during the 1961-2007 period at all the 5 weather stations situated in the Prahova River Basin: Omu Peak, Predeal, Sinaia 1500, Câmpina and Ploieşti.

These monthly average air temperatures were uniformly distributed over the entire area of the analyzed river basin using the Thiessen polygons method, thus obtaining one string of temperatures that expresses the average condition for the entire area of the Prahova River Basin.

The Thiessen polygons method was also used to determine the uniform distribution of the monthly amounts of rainfall recorded at the same weather stations. Thus, there have been obtained one string of data regarding the monthly amounts of rainfall and valid for the entire area of the analyzed river basin.

The hydrological data used for the simulation of the liquid run-off in different climate scenarios was represented by the monthly average liquid discharges recorded in the section of the Adâncata river station during the 1961-2007 interval.

Since the water resource was discussed in terms of below-average water resource which is characteristic to low-water periods, there have also been used the minimum monthly average liquid discharges, while for the above-average water resource, characteristic to high-water periods, there have been taken into account the maximum monthly average liquid discharges.

3. Outcomes

The analysis of the impact of potential climate changes upon the average liquid flow on the Prahova River in the section of Adâncata river station has been performed by comparing the monthly average water discharges obtained after applying various hypothetical climate scenarios with the help of the WatBal model to the monthly average water discharges already determined for the standard scenario (scenario 0).

3.1. The estimation of the minimum monthly multiannual average flow in the Prahova River Basin at Adâncata river station for the climatic scenarios 1.1 – 1.14

It can be observed (fig. 1) that *the most important positive deviations* between the minimum monthly multiannual average flow simulated with the WatBal model for various climatic scenarios and the flow determined for scenario 0 are encountered in scenarios 1.2 in April (+13.1%), May (+13.38%) and June (+15.36%), 1.7 for the same months of April, May and June, but at a lower amplitude than in the previous case (+10.01%, +9.52% and 13.33%) and 1.12, for the same months of the warm season, April through July, but with values between 5% and 10%.

It must be mentioned that the climatic scenarios listed above propose a 20% increase in the amount of rainfall as compared to the amounts recorded in the 1961-2007 interval, combined with an alteration of the mean monthly temperature conditions of 0°C in the case of scenario 1.2, +2°C in the case of 1.7 and +4°C in the case of 1.12.

It can also be seen that even if the increase in the amount of rainfall is the same for all the three above-mentioned climatic scenarios (+20%), the variation of the temperature regime slightly modifies the amplitude of the simulated discharges deviations, more specifically if the temperatures remain unaltered form the ones observed in the reference period (1961-2007) the deviations of the simulated discharges tend to be somehow more important than if temperatures increase by 2 or 4°C. Thus, June exhibits a deviation of +15.36% in the case of scenario 1.2 (which simulates the mean monthly liquid run-off with a 20% increase in the amount of rainfall but keeping the same temperature conditions as the ones observed in the 1961-2007 interval), +13.33% in the case of scenario 1.7 (which adds 2°C to the basic temperature conditions) and +9.5% in the case of scenario 1.12, which adds 4°C to the 20% increase in the amount of precipitation (fig. 1).

This can be motivated by a decrease of the water input into the hydrological system of the Prahova River Basin, caused by higher rates of evaporation as a consequence of the increasing temperatures, even if rainfall amounts are simulated to be 20% higher than the recordings of the reference period.

The most important negative deviations between the minimum monthly multiannual average flow and the flow determined for scenario 0 are provided by the climatic scenarios 1.4, 1.9 and 1.14 during the warm season months, more specifically April, May, June and July. The deviations tend to be greatest in June (-13.41% in the case of scenario 1.4, -14.21% in the case of scenario 1.9 and -14.73% in the case of 1.14) and of a lesser amplitude during the other months of the year, ranging between -5 and -10% (fig. 1).

These scenarios simulate the minimum monthly multiannual average flow within a 20% decrease in the amount of rainfall, combined with an alteration of the mean monthly temperature conditions of 0°C (scenario 1.4), +2°C (scenario 1.9) and +4° (scenario 1.14). Climatic scenario 1.14 exhibits the greatest deviation of the simulated minimum monthly average flow (-14.73%), caused by a 20% reduction of the rainfall amounts combined with a 4°C temperatures increase (fig. 1).

It is obvious that the greatest impact of future climate changes upon the low-water flow and below-average water resources in the Prahova River Basin will take place in the mid-spring to mid-summer months (April-July), while the other months of the year, although affected by the positive or negative alterations of the main climatic parameters, show lower deviations as compared to the values of scenario 0 (fig. 1).

This situation may be explained by the warmer air temperatures that are common to the above-mentioned period, which combined with a 20% decrease in the amounts of rainfall would cause a subsequent decrease of the minimum monthly average liquid flow on the Prahova River, while combined with a 20% increase in the amount of rainfall would determine an increase of the simulated flow, provided by the input into the hydrological system of a larger amount of water. This increase may be amplified if we taken into consideration the fact that the rain pattern of the warm season months is characterised by heavy downpours and moreover, the months of April and May are susceptible to developing a rich flow on rivers due to snow melting in the mountainous areas, as well.

The least significant deviations, involving a weak impact upon the mean water resource in the Prahova River Basin, are characteristic to climatic scenarios 1.5, 1.6, 1.10 and 1.11. These scenarios bring mild alterations of the basic climatic conditions observed during the 1961-2007 interval, proposing either a maintenance of the amounts of rainfall or a moderate 10% increase, combined with a maintenance or a 2°C increase in mean monthly temperatures.

The results of the simulations performed for these mild scenarios prove small, insignificant deviations, of less than 5% (fig. 1).

3.2. The estimation of the monthly multiannual average flow in the Prahova River Basin at Adâncata river station for the climatic scenarios 1.1 – 1.14

It must be noticed that the positive and negative deviations produced by possible climate changes upon the monthly multiannual average flow at Adâncata River Station on Prahova River share a more uniform distribution thorough the 12 months of the year compared to the deviations observed for the minimum monthly multiannual average flow (fig. 2).

This is because the monthly multiannual average flow is a synthesis of the minimum monthly average flow, characteristic to the low-water regime and of the maximum monthly average flow, characteristic to the high-water regime. Thus, it exhibits a more balanced distribution during the 12 months of the year, without important discrepancies between the months of the warm season (April-September) and those of the cool season (October-March).

The most important positive deviations are encountered for climatic scenarios 1.2, 1.7 and 1.12, the same as for the minimum monthly average flow, but with grater values (fig. 2).

Thus, a massive +41.54% deviation can be observed for May in scenario 1.2, followed by an important +29.19% deviation in May, scenario 1.7 and +18.28% in May, scenario 1.12 (fig. 2).

The other months of the warm season (April, June, July, August and September) also exhibit important deviations of the simulated monthly multiannual average flow compared to the average flow of scenario 0 (basic climatic conditions), while the months of the cold season (October through March) display lower amplitude deviations, but still accounting for more than 50% of the deviation determined for the month with the highest impact (which is May).

It must be recalled that climatic scenarios 1.2, 1.7 and 1.12 are the ones that propose a 20% increase in the amount of precipitation, combined with an alteration of the temperatures regime of 0°C (scenario 1.2), +2°C (scenario 1.7) and +4°C (scenario 1.12).

Regarding *the most important negative deviations* of the monthly multiannual average flow relative to the monthly average flow determinate for scenario 0, the greatest values have been simulated for climatic scenarios 1.4, 1.9 and 1.14. Among these, the months with the greatest negative impact are in the warm period, from April to August.

However, May is the month that marks the strongest negative impact determined by the proposed climatic conditions upon the monthly multiannual average flow (a 20% decrease in the amount of rainfall and a +2°C, respectively +4°C temperature increase), with negative deviations of -28.57% in scenario 1.4, -31.09% in scenario 1.9 and -32.95% in scenario 1.14 (fig. 2).

It can be noticed that the amplitude of the negative deviations varies inversely as compared to the amplitude of the positive deviations, determined by the climatic scenarios that propose an increase in the amount of rainfall.

Thus, the negative impact provided by the climatic scenarios that simulate a 20% decrease in the amount of rainfall combined with a 0-4°C temperature increase is getting more important as temperatures rise, as a consequence of the more intense evaporation which would create premises for more severe water shortages in the river basin (thus the water loss would exceed the influx), while the positive impact provided by the climatic scenarios that simulate a 20% increase in the amount of rainfall combined with a 0-4°C temperature rise is getting less important as temperatures rise, because the intense evaporation would mitigate the influx of water determined by more abundant rainfall.

The influence upon the monthly multiannual average flow is less significant for scenarios 1.5, 1.6 and 1.11, the simulated deviations (either positive or negative) being less than 10% if compared to the monthly average flow of scenario 0 (basic climatic conditions), even lower than 5% in case of scenario 1.11, which enables us to state that a 4°C temperature rise combined with a 10% increase in the amount of rainfall would have an insignificant impact upon the average monthly flow considered for the entire Prahove River Basin, summoned at Adâncata River Station (fig. 2).

3.3. The estimation of the maximum monthly multiannual average flow in the Prahova River Basin at Adâncata river station for the climatic scenarios 1.1 – 1.14

The maximum monthly multiannual average flow must be regarded as the high-water resource of a river basin.

It can be observed that the most important positive deviations between the maximum monthly multiannual average flow simulated for the various climatic scenarios and the same type of flow determined for the basic climatic conditions (scenario 0) are encountered, as for the other two types of liquid flow that have been analyzed, in climatic scenarios 1.2, 1.7 and 1.12 and within them, the months that show the greatest impact are March, April, May, as well as August and September (fig. 3).

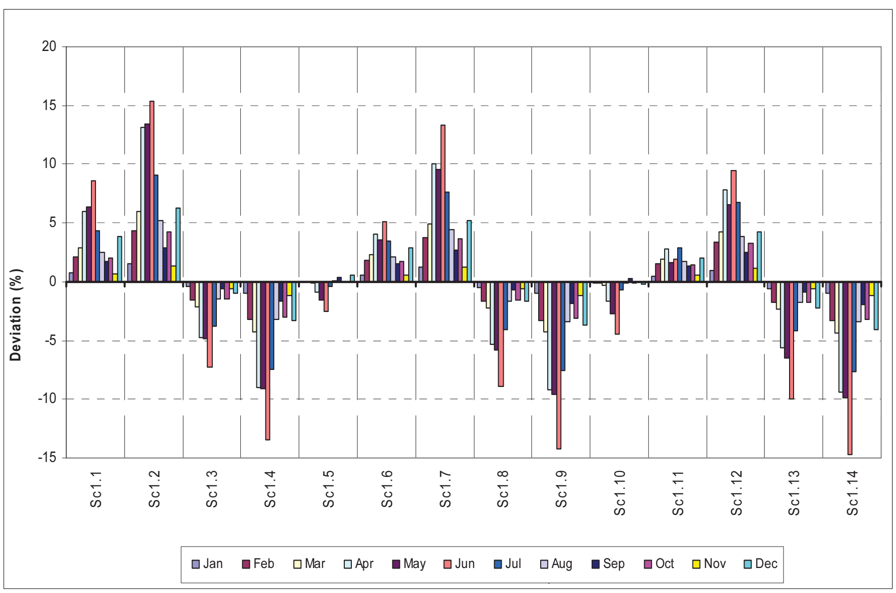

Figure 1. The percentual deviation of the minimum monthly multiannual average flow in the Prahova River Basin at Adâncata river station for the hypothetical climatic scenarios 1.1-1.14.

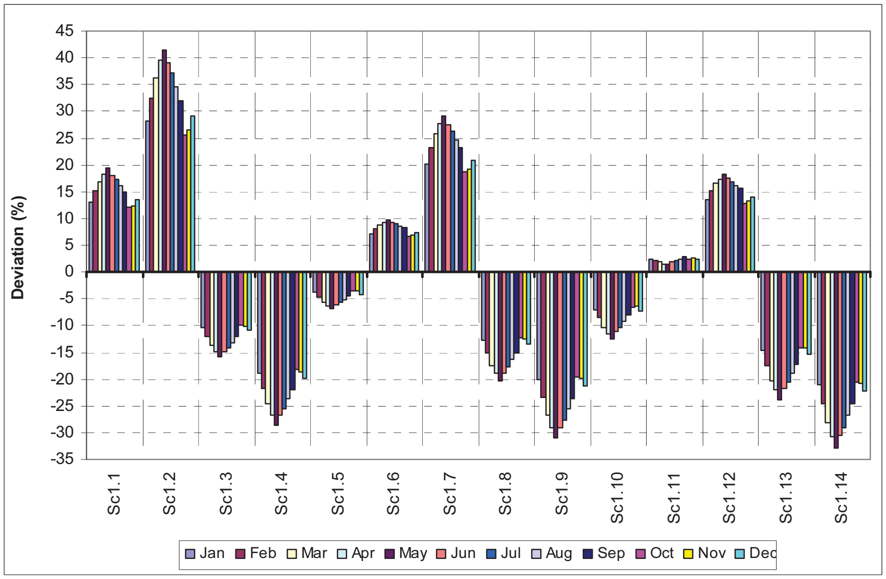

Figure 2. The percentual deviation of the monthly multiannual average flow in the Prahova River Basin at Adâncata river station for the hypothetical climatic scenarios 1.1-1.14.

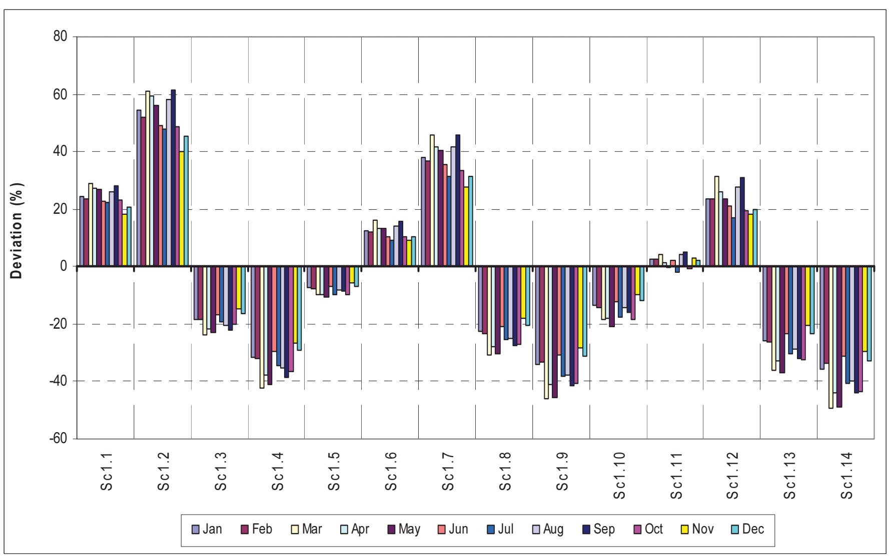

Figure 3. The percentual deviation of the maximum monthly multiannual average flow in the Prahova River Basin at Adâncata river station for the hypothetical climatic scenarios 1.1-1.14

It can also be observed, that unlike previous simulations carried out for the minimum and mean monthly multiannual liquid flow, the simulations performed for the maximum monthly average flow indicate that there are two intervals that share the greatest impact, in terms of the most important positive deviations identified related to scenario 0 (March-May and August-September).

It must be taken into consideration that the above mentioned climatic scenarios propose a 20% increase in the amount of monthly rainfall combined with an alteration of the temperatures regime between 0°C (scenario 1.2) and +4°C (scenario 1.12).

The *maximum positive deviations of the March-May period* (spring months) are caused by a rich, high-waters, hydrological regime, which is characteristic to the spring months, as a consequence of the snow melting thorough the river basin, especially thorough the mountainous regions, combined with serious amounts of rainfall, particularly during the months of April and May.

A 20% increase in the amount of rainfall would trigger important positive deviations, of up to 60% over the basic climatic conditions liquid flow, especially for March and April in scenario 1.2 (fig. 3).

The *considerable positive deviations of August and September*, which reach 58.02% in August and 61.56% in September in the hypothesis of scenario 1.2, 41.91% in August and 45.69% in September in scenario 1.7 and 27.69% in August and 31.02% in September in scenario 1.12 may be explained by the scarcity of the rain pattern that normally is recorded during this period of the year, which would be easily disturbed by a 20% increase in amount, given that the late-summer and early-autumn rains usually have a torrential character and can easily trigger severe events (fig. 3).

The *most important negative deviations* of the maximum monthly average flow are seen in scenarios 1.4, 1.9 and 1.14, the highest impacted months being March-May and August-September. The amplitude of the negative deviations is similar to that of the positive ones, but unlike the positive scenarios, that were proposing an increase in the amount of rainfall, the negative scenarios, that suggest a decrease in the precipitation amounts, exhibit an inverse distribution of the amplitude of these deviations (fig. 3).

More precisely, in case of positive scenarios, that suggest an increase in the amount of rainfall, the positive deviations of the maximum monthly average flow tend to reduce as temperatures rise, as a consequence of the intensifying evaporation that lowers the input of water into the hydrological system, while in the case of negative scenarios, that suggest a decrease in the amount of rainfall, the negative deviations are gaining in amplitude as temperatures rise, worsening the water resource scarcity.

The most impacted months are March through May, as well as August and September in scenario 1.14, the amplitude of the negative deviations of the maximum monthly average flow as related to the basic climatic conditions flow reaching -49.15% in March, -43.78% in April, -49.09% in May, while August and September show -39.74%, respectively -43.79% lower maximum monthly average discharges compared to the ones in scenario 0 (fig. 3).

It must also be reported that scenario 1.14 is the most pessimistic of the entire range of 14 climatic hypotheses that were taken into analysis. It suggests that the high-water resource would decrease with over 40% as compared to the basic conditions flow in 6 months of the year: March, April, May, July, September and October.

The *least significant impact of the hypothetical climate changes upon the maximum monthly average flow* can be remarked within scenarios 1.5, 1.6 and 1.11, the latter showing only slight variations on both sides of the 0% deviation line, which proves that a 10% increase in the amount of rainfall together with a 4°C warming of the climate would not have a major influence upon this specific type of liquid flow.

Except 1.11, there are 5 climatic scenarios (1.1, 1.2, 1.6, 1.7 and 1.12) which suggest an increase of the maximum monthly average flow and 8 scenarios (1.3, 1.4, 1.5, 1.8, 1.9, 1.10, 1.13 and 1.14) that indicate a decrease of this type of liquid flow (fig. 3). Thus, it can be appreciated that there is a state of disequilibrium between the number of climatic hypotheses which suggest an increase tendency of the maximum monthly average flow and the number of hypothesis which suggest a decrease tendency.

3. Conclusions

The present study proves that rainfall is the main climatic factor responsible for influencing the regime of the mean liquid flow and therefore the mean water resource in the Prahova river basin, while temperatures, although capable of slightly altering the hydrological regime of rivers, play a secondary role. Rising temperatures may somehow determine an important water shortage if correlated with a decrease in the amount of rainfall, as it was the case of scenario 1.14. Otherwise, temperatures can influence very little the liquid flow on rivers (see scenario 1.10).

Based on the computer simulations applied for Adâncata river station, for all the 14 climatic scenarios we have taken into consideration, it is very likely that the mean monthly water resource in the Prahova river basin (including the low-water and high-water resources) is going to decrease.

The demonstration of this conclusion comes from the fact that out of the 14 climatic hypotheses we have considered, 8 indicate a decrease of the mean water resources (1.3, 1.4, 1.5, 1.8, 1.9, 1.10, 1.13 and 1.14), while the other 6 indicate an increase of the discussed parameter. Even so, the increase that has been observed for scenarios 1.1, 1.2, 1.6, 1.7, 1.11 and 1.12 is of lower amplitude than the decrease shown by the other 8 scenarios, being almost negligible for climatic hypotheses 1.6 and 1.11.

Therefore, it can be concluded that, out of the entire range of climatic scenarios that have been analyzed, most of them indicate that water resources in Prahova River Basin, represented by the liquid flow at Adâncata River Station, will suffer a considerable quantitative drop.

REFERENCES

1. BISWAS, A., K. (2010), *Water for a Thirsty Urban World*, Brown Journal of World Affairs. Fall-winter, **XVII**, *I*;
2. DOOGE J., C., I. (1992), *Hydrologic Models and Climate Change*, Journal of Geophysical Research, 97(D3): 2677-2686.
3. KACZMAREK, Z. (1993), *Water Balance Model for Climate Impact Analysis*, ACTA Geophysica Polonica, **41**, *4*, p.1-16.
4. STĂNESCU, V.,A., CORBUŞ, C., SIMOTA, Marinela (1999), *Modelarea impactului schimbărilor climatice asupra resurselor de apă*, Edit. HGA, Bucureşti, p. 7, 109-117;
5. YATES D. N. (1994), *WATBAL - An Integrated Water Balance Model for Climate Impact Assessment of River Basin Runoff*, IIASA Working Paper, WP-94-64, Laxenburg, Austria.
6. *** *Atlasul Cadastrului Apelor din România*, Bucureşti, 1992, 356 p.