Detecting Changes in Annual Precipitation Trends During the Last Two Climatic Periods (1955-1984 and 1985-2018) in Nestos River Basin, N. Greece

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Abstract

Precipitation spatio-temporal changes can have an important impact on natural ecosystems. In this study, we assess the annual precipitation spatial distribution along with its changes along two climatic periods (1955-1984 and 1985-2018) in Nestos River (N. Greece), an area that hosts a variety of ecologically important habitats. The annual data were obtained from nine long operating stations. For the analysis, the Mann-Kendall and the Sen's slope methods were applied to detect the trends, evaluate their significance and estimate the changing rates of precipitation. Results indicate a high spatial variability of precipitation in the sub-basin with higher and increasing values during the latest years compared to the past for the mountainous (northern) part of the basin, whereas the coastal and altitudinal lower (southern) part receive less precipitation. In the coastal zone, a shift in precipitation is identified from west to east, with the eastern coastal zone to become more and more rapidly dry compared to the past. This is critical for the conservation of the valuable but vulnerable priority habitats in the coastal zone, considering their high water requirements.

Keywords

Precipitation trends, Nestos River, Mann-Kendall test, Sen slopes

1. Introduction

Precipitation trends on a global level present high spatial and temporal variability [1]. Today, North Europe is more humid and the Mediterranean more arid compared to the past, whereas eastern Mediterranean regions are anticipated to face even more arid conditions in terms of reduced precipitation within the next years [2]. The precipitation trends in the Mediterranean basin appear to be generally negative with higher decreasing rates of about -10% in its eastern areas and less intense in the western part of the basin [3], however this general pattern is characterized by high spatial variability [1, 4-8]. Such changes are expected to have serious ecological impacts considering that the Mediterranean basin is characterized as both a biodiversity and a climate change hotspot [9, 10]. A reduction in precipitation may impose significant changes in net productivity and plants growth dynamics affecting highly the natural rain-fed ecosystems [11, 12]. In addition, long-term monitoring may portray the potential of trees' recovery in case of climatic vagaries [13].

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In Greece, recent climate is more arid compared to the past [14, 15]. Proutsos et al. [16] assessed precipitation trends by analyzing data of the period 1951-2006 obtained from 32 gauged stations in Greece and found significant decreasing annual trends, in most cases, with an average changing rate of –3.7 mm/y, with high seasonal and spatial variability. The precipitation trends are generally negative and more intense in the islands [17, 18], whereas in the continental areas are less intense and even become positive during the last years [19]. In N. Greece, Stefanidis and Alexandridis [20], detected decreasing but insignificant precipitation trends for Pertouli, whereas positive trends were found in Taxiarchis forest sites. Proutsos et al. [21] also studied the precipitation trends in the coastal area of Nestos Delta (N. Greece) and found statistically significant decreasing trends mainly at lower altitudes, and increasing higher.

The present study is based on the study of Proutsos et al. [21] focused on the identification of precipitation trends in Nestos Delta for the period 1956-2017, which was based on precipitation data from five meteorological stations. In this study, we have expanded the analysis by assessing annual precipitation time series from nine rain gauge stations inside and nearby Nestos' River Greek sub-basin and we performed the analysis separately for two climatic periods (1956-1984 and 1985-2017) in order to identify and evaluate the different changing spatial patterns of the annual precipitation during the latest climatic period compared to the respective changes in the previous one.

2. Study Area, Data and Methods

Nestos (Mesta) is transnational river, with its sources in southern Bulgaria (Rila mountains). It flows about 126 km in Bulgaria and about 130 km in Greece, whereas the total catchment area is 5,613 km² [22]. The Greek part of the basin (Figure 1) hosts a variety of crops, and also natural ecosystems with high ecological interest. Forested parts of the basin are strictly protected as Natura 2000 sites, with most significant the fan-shaped Nestos Delta [23], which extends to an area of about 23,000 ha. The Delta is considered one of the most important wetlands of Greece, due to its size and the variety of habitats (28 types) located inside the protected area [24], among which three of them are characterized as of high priority: 1150* (coastal lagoons), 3170* (Mediterranean temporary ponds) and 91E0* (Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior)*. More information about the site can be found in Proutsos et al. [25].

Figure 1: Aspect of Nestos River in N. Greece.

The climate in the broader area is humid according to UNEP's [26] climate zone aridity classification system based on Thronthwaite's [27] aridity index AI [14, 15], whereas precipitation changes have been occurred during the last 50 years with decreases in the coastal zone and increases in the mountainous area [21], indicating that in the coastal zone, the natural vegetation, is anticipated to be more vulnerable in case of climatic vagaries in the future.

For this study, annual precipitation data series of nine gauged stations were used (Figure 2, Table 1). The analysis was performed for two distinct climatic periods: 1955-1984 (1st climatic period) and 1985-2017 (2nd climatic period) on an annual time step. For each data series the Mann-Kendall test [28, 29] was applied to detect the trend and identify the level of significance. The Mann-Kendall test is a non-parametric method, widely used in trend analysis of hydroclimatic data [16, 30-35] and is considered as a reliable tool in identifying monotonic linear and non-linear trends in non-normal datasets [36]. The trends slopes (Q) were estimated by the Sen's method [37], accepting the existence of linearity in the dataset [38, 39]. For the calculations the MAKESENS 1.0 software was employed [40], whereas the spatial patterns were developed by using the Kriging's technique [41].

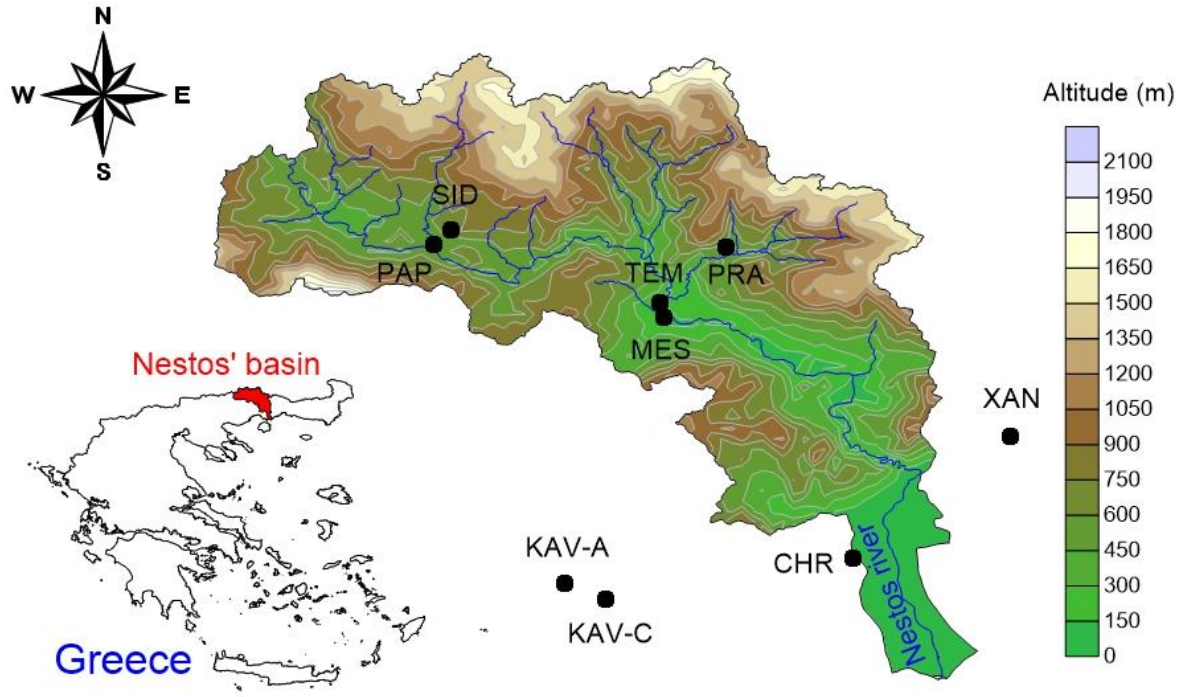

Figure 2: Map of the Nestos River sub-basin in Greece, indicating also the positions of the rain gauged stations.

Table 1
Meteorological stations

Code	Site name	Longitude	Latitude	Altitude (m)	Operating period	Owner
CHR	Chrysoupoli	24.60°E	40.93°N	60	1985-2017 (n=33)	HNMS
KAV-A	Kavala (Amygdaleonas)	24.38°E	40.93°N	60	1956-1984 (n=29)	HNMS
KAV-C	Kavala (city)	24.41°E	40.94°N	5	1986-2004 (n=19)	HNMS
MES	Mesochori	24.47°E	41.27°N	120	1963-2018 (n=56)	DEH
PAP	Papades	24.21°N	41.35°N	830	1963-1990 (n=28)	DEH
PRA	Prasinada	24.55°E	41.35°N	660	1962-2018 (n=57)	DEH
SID	Sidironero	24.23°E	41.37°N	570	1963-2018 (n=56)	DEH
TEM	Temenos	24.47°N	41.29°N	920	1963-1990 (n=28)	DEH
XAN	Xanthi	24.88°E	41.13°N	83	1955-2011 (n=57)	HNMS

3. Results and Discussion

The spatial distribution of the annual precipitation based on the meteorological data of seven stations for the 1st climatic period (1955-1984) in comparison with the respective pattern for the 2nd climatic period (1985-2018) derived from data by 6 meteorological stations are depicted in Figure 3. The pattern for the 1st climatic period indicates that in Nestos basin, precipitation presents annual values varying from 580.1 mm in KAV-A station to 1533.5mm in XAN. The values were lower at the upper and altitudinal higher part of the sub-basin, whereas, at the Delta (lower part) the magnitudes were much higher. For the 2nd climatic period, the spatial pattern differentiated. The mountainous areas, located in its upper (northern) part of the basin, received more precipitation compared to the past, while the lower (southern) part appears to have more dry conditions. This is very important, considering that the priority habitats 3170* and 91E0*, that are hosted at the lower part of the basin, require high water availability to be preserved. This precipitation variability and its change to more arid conditions in the Delta will probably affect the vegetation distribution in the area and increase the vulnerability of the priority habitats. It appears that the habitat 3170* (temporary ponds) is no longer present at the western lower part of the sub-basin. In a recent recording, we found only one new temporary pond at the eastern part of the Delta and in an altitudinal higher location. This pattern indicates that the recent precipitation distribution in the basin, in association with the operation of the dams in Thysavros and Platanovrisi (located near the MES station), has changed the vegetation pattern especially for the high risk habitats with increased water requirements.

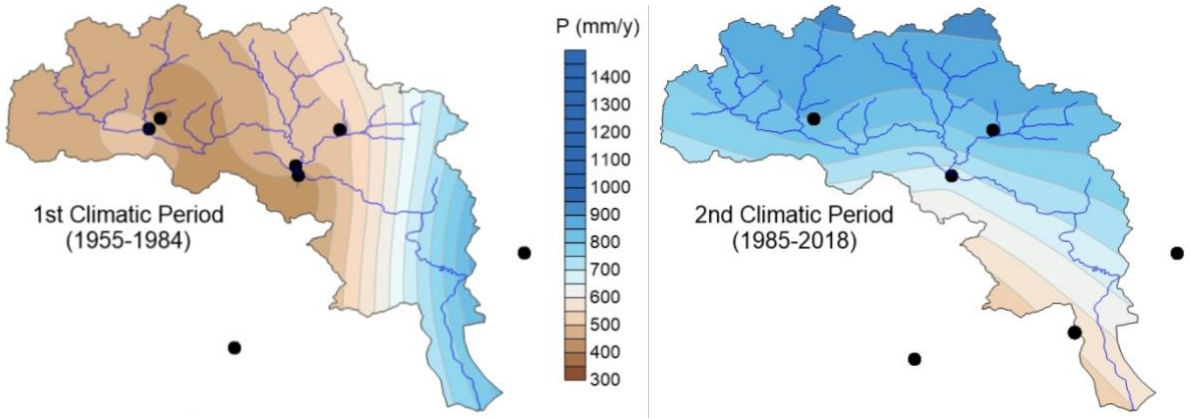

Figure 3: Spatial pattern of the annual precipitation in Nestos sub-basin in N. Greece for the two climatic periods (1955-1984 and 1985-2018). Black dots indicate the positions of the meteorological stations used for the spatial interpolation.

It should be noted, however, that during the recent climatic period, precipitation has increased in magnitude at the upper and altitudinal higher parts of the basin, indicating that the local vegetation will face more favorable conditions for its development compared to the past. These results are in line with the findings by Proutsos et al. [21], who also address issues for the viability of the habitats at the lower eastern part of the Delta in Nestos.

Apart from the absolute magnitudes of precipitation, extremely important is to investigate its changing rates during the two time periods. Proutsos et al. [21] analyzed data of the period 1956-2017 from five meteorological stations and identified a general increasing but highly variable trend in annual precipitation for the basin, with changing rates varying from -9.29 mm/y in KAV stations to +5.9 mm/y in SID, whereas the negative trends were detected at the lower part of the basin. In the present study, the changing rates differ between the two climatic periods. During the 1st climatic period the precipitation trends for most stations are not significant (Figure 4). However, at the eastern lower part of the basin, XAN station presented positive and very strong (a= 0.001) trend, while at the altitudinal higher and northern station SID a strong (a=0.05) negative trend was detected. Positive but not significant trends were detected for two stations (MES and KAV-A), whereas PAP, TEM and PRA had negative but also not significant trends. This pattern has changed during the 2nd climatic period when all stations except KAV-C presented positive trends. Specifically, MES, SID and CHR stations had

increasing and significant (a=0.05) annual trends, whereas XAN presented also a positive but not significant trend. The only station with decreasing precipitation was KAV-C. This trend is very strong (a=0.001) indicating a rapidly changing climate to drier conditions in the southern coastal part of the basin. In this period the climate in the mountainous part became more favorable for the development of natural vegetation compared to the past, but at the lower part of the basin, vegetation deals with more dry conditions, that is rapidly changing the recent years.

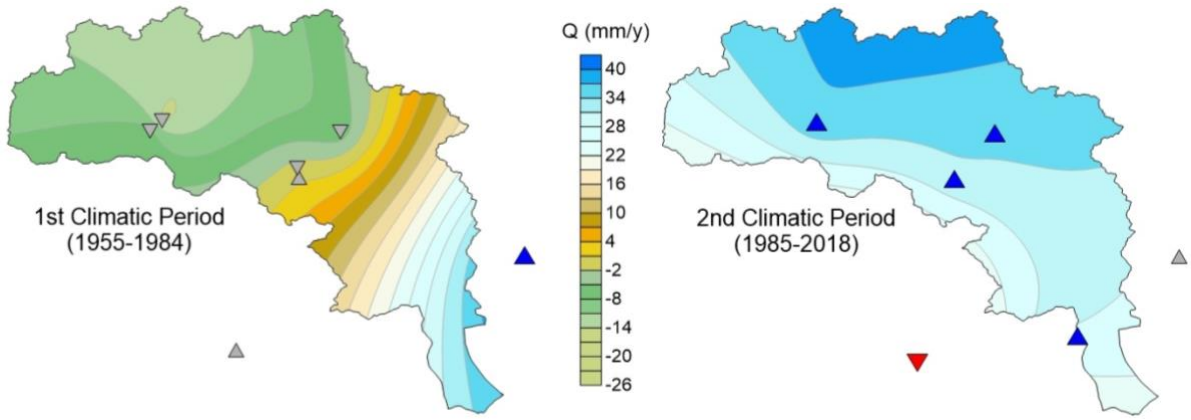

Figure 4: Spatial pattern of the annual precipitation trends in Nestos sub-basin (N. Greece) for the two recent climatic periods (1955-1984 and 1985-2018). The triangles indicate the positions of the meteorological stations with upward-facing for positive and downward-facing for negative trends. Grey color indicated the not significant trends, whereas blue and red arrows show the positive and negative significant trends, respectively.

4. Conclusions

The precipitation patterns in the Hellenic part of Nestos' basin is characterized by high spatial and temporal variability. The northern and mountainous basin parts receive increased precipitation compared to the past and these rates are significantly increasing during the last climatic period. At the lower (coastal) and southern part of the basin, where habitats of high ecological value are located, precipitation appears to have decreased, while in the latest climatic period the decreasing rates, mainly at the lower western part of the basin are more rapid and strong. The habitats in the Delta are highly vulnerable and are expected to be highly affected by the climate variability in the future, due to the diminished annual precipitation and the rapidly changing climate to more arid conditions. To further investigate the possible impacts of the changing climate on the natural vegetation conservation in the region, continuous climate monitoring is necessary. It is also needed to investigate the temperature and evapotranspiration patterns in order to have more reliable conclusions. The operation of the dams should also be evaluated. In future work, a drought assessment and an analysis of the changes in the seasonal and monthly precipitation patterns are necessary to enhance our knowledge for the region, in terms of the possible future risks for the highly sensitive and extremely important, for its ecological value, natural ecosystem of Nestos.

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6. References

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