50-year precipitation trends in Nestos Delta-Natura 2000 site

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Abstract
Nestos Delta (north Greece) is a complex ecosystem of high ecological importance, protected by the European Union as a Natura 2000 site. The presence of the habitats 3170* and 91E0*, which are highly connected with water resources availability, impose the continuous monitoring of precipitation in the area, since even minor changes of the precipitation regime could have a significant effect on the habitats' viability. Aim of this work is to detect significant precipitation changes by analyzing datasets from 5 nearby station for a time period of about 50 years. The results indicate statistically significant decreasing changes mainly at lower altitudes, and increasing at higher.
Keywords: Precipitation, Trends, Mann-Kendall, Sen

1. Introduction

Precipitation plays an important role in natural vegetation succession, conservation and drought tolerance. Its changes can affect species dynamics in plant communities. To evaluate the impacts of changing precipitation on natural vegetation, continuous monitor is essential for adopting, in time, adaptation and mitigation measures to protect local flora and fauna, especially in the Mediterranean, which has been identified as a climate change (Diffenbaugh and Giorgi 2012) and biodiversity hotspot (Myers et al. 2000). In Greece, the last decades, changes in temperature and precipitation have been identified in several places, even in mountainous forest areas (Proutsos et al. 2009, 2010). The aim of this study is to investigate the precipitation trends in Nestos Delta (Natura 2000 site), north Greece, during the last 50 years.

2. Materials and methods

Monthly precipitation data from five long operating meteorological stations in Nestos Delta were used in this study (Table 1), covering the time period 1956-2017. Data were analyzed on monthly, seasonal and annual basis and the trends were identified by employing the Mann-Kendall non parametric test at different confidence levels. Mann-Kendall test is widely used for climatic and environmental time series trend evaluation, since it is a reliable method to identify monotonic linear and non-linear trends in non-normal data sets (Helsel and Hirsch, 1992). The slope Q of each trend, was estimated by the method of Sen, as a median of all possible slopes.

Table 1. The 5 stations used for the trend analysis

Station	Coords	Alt	Period	Owner
XAN	24.88°E 41.13°N	83m	1955-2011 (n=57)	HNMS
SID	24.23°E 41.37°N	570m	1963-2017 (n=55)	DEH
PRA	24.55°E 41.35°N	660m	1963-2017 (n=55)	DEH
MES	24.47°E 41.27°N	120m	1963-2017 (n=55)	DEH
KAV	24.41°E, 40.94°N	6m	1956-2004 (n=46)	HNMS

3. Results and concluding remarks

The pattern of precipitation changes from the data analysis of 5 meteorological stations near Nestos Delta is presented in Table 2. On an annual basis, a highly significant (a=0.001) decreasing trend (Z=-4.19) was detected in KAV (alt. 6m) for the time period 1956-2004, with an average slope of -9.29 mm/y, indicating that drier conditions persist nowadays compared to 1956. At higher altitudes, generally, the trends are not significant. However, at altitude 570m in SID, the annual precipitation appears increasing for the period 1963-2017 with a rate of +5.99 mm/y, even if this trend is only significant at a confidence level a=0.05.

The seasonal trend analysis, shows different changing rates for precipitation. Rainfall in winter has decreased significantly (a=0.001) since 1950s in KAV with an average rate of -3.05mm/y (Z=3.73), but has not significantly changed in other stations. In spring, decreasing trends were identified for KAV (-1.58mm/y, Z=-2.22) and XAN (-2.40mm/y, Z=-2.31) and increasing for SID (+1.56mm/y, Z=+2.45) at a=0.05. Respectively in autumn decreasing trends were also identified for KAV (rate -2.24mm/y, Z=-3.83 at a=0.001) and XAN (-2.69 mm/y, Z=-2.14 at a=0.05) and increasing for SID (+2.23mm/y, Z=+3.03 at a=0.01). In KAV, precipitation trends were found negative for most months and were highly significant (a=0.001) for January and June. In SID an also significant (a=0.001) increase was identified in September.

The decreasing precipitation trends are in line with the findings of other studies for the Mediterranean (Tanarhte et al. 2012), but for north Greece also positive trends were found (Pakalidou and Karacosta, 2018). The above described precipitation changes indicate that a translocation of rainfall has occurred the last 50 years in Nestos Delta with significant decreases of available precipitation water at the coastal zone and increases at the mountainous region. Except for the altitudinal translocation, changes are also identified comparing western and eastern sites. The rainfall pattern also changed with increasing precipitation rates at the eastern areas and decreasing or less increasing at the western, with respect to their altitudinal position. Such changing pattern is expected to affect natural vegetation in the future and especially habitats with high water requirements like the riparian forest (91E0*) or the temporary seasonal ponds (3170*) of Nestos. This effect is evident even today, since the habitat 3170* has a decreasing presence in the area and appeared in new places located eastern from the ones recorded in the past, obviously in an effort to adapt to a climate-changing environment. However, further investigation is needed, concerning the vegetation dynamics in the area, which is an ongoing research work under the framework of the LIFE PRIMED project.

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Table 1. Mann-Kendall test results (Z) for the evaluation of precipitation trends in Nestos Delta region and Sen slope (Q) estimates in (mm/time period) for the trends quantification.

	STATION									
	XAN		SID		PRA		MES		KAV	
Month	**Z**	**Q**	**Z**	**Q**	**Z**	**Q**	**Z**	**Q**	**Z**	**Q**
January	**-1.84**	**-1.25**	0.64	0.39	-0.39	-0.17	-0.22	-0.05	**-3.66**	**-1.20**
February	**-1.84**	**-1.06**	0.06	0.04	-0.92	-0.41	-0.71	-0.27	-1.42	-0.36
March	-1.28	-0.65	**1.85**	**0.72**	1.34	0.43	1.31	0.31	**-2.47**	**-0.72**
April	-2.69	-1.22	1.40	0.39	-0.16	-0.05	-0.42	-0.06	-0.77	-0.18
May	**-1.84**	**-0.91**	**1.69**	**0.55**	0.66	0.18	0.90	0.22	**-2.22**	**-0.50**
June	**-2.29**	**-1.14**	**2.44**	**0.76**	0.43	0.14	1.34	0.42	**-4.33**	**-0.92**
July	**-2.05**	**-0.80**	-0.40	-0.09	0.12	0.07	0.92	0.24	**-1.77**	**-0.29**
August	-1.36	-0.26	0.04	0.01	0.25	0.08	1.23	0.38	0.54	0.06
September	**-2.20**	**-0.52**	**3.93**	**1.08**	**1.80**	**0.40**	1.10	0.29	**-2.36**	**-0.40**
October	-1.47	-0.76	**1.96**	**0.72**	0.60	0.26	0.69	0.18	**-2.39**	**-0.72**
November	-1.01	-0.68	**1.89**	**0.67**	0.81	0.32	0.12	0.03	**-2.25**	**-0.81**
December	-0.69	-0.59	0.88	0.58	0.23	0.16	-0.43	-0.18	-2.62	-1.30
Season										
Winter	-1.34	-2.65	0.81	1.08	-0.06	-0.08	-0.63	-0.49	**-3.73**	**-3.05**
Spring	**-2.31**	**-2.40**	**2.45**	**1.56**	**1.67**	**0.89**	0.78	0.40	**-2.22**	**-1.58**
Summer	**-2.08**	**-1.94**	1.50	0.87	0.62	0.36	**1.85**	**1.10**	-2.94	-1.53
Autumn	**-2.14**	**-2.69**	3.03	2.23	1.54	1.02	0.52	0.30	**-3.83**	**-2.24**
Annual										
Year	-1.27	-7.50	**2.52**	**5.99**	1.51	2.75	0.77	1.08	**-4.19**	**-9.29**
Hydro year	-0.88	-6.36	2.85	5.91	0.77	1.10	0.53	0.89	**-4.09**	**-9.33**
			α=0.001		α=0.01		**α=0.05**		**α=0.1**	

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