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SPATIAL AND TEMPORAL DISTRIBUTION OF RAINFALL AND TEMPERATURE IN MACEDONIA, GREECE, OVER A THIRTY YEAR PERIOD, USING GIS

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Abstract

Due to increased demand and use of water resources, the European Union has established the (WFD) Water Framework Directive 2000/60 for Community action in the field of water policy. In order to achieve better water protection and management, Member States must identify and analyse European waters, on the basis of individual river basin and district.

Precipitation and air temperature are directly related and at the same way interacted to the hydrological cycle and therefore with water resources. The objective on this study is to present the spatial and temporal distribution of precipitation and air temperature in Macedonia, by using GIS software (ArcMap 9.3).

The data used were retrieved from 82 different meteorological stations, which belong to the Ministry of Rural Development and Food, and correspond to the thirty year period (1974-2004); all stations provided continuous daily data of precipitation while 43 of them provided also daily data of temperature. The annual temperature range and the annual total precipitation amount were calculated, at each individual station, for the thirty years of the examined period. By using GIS software and triangular interpolation scheme, the thematic maps of Macedonia for the aforementioned parameters and thermal continentality K were created. Furthermore, possible mean annual evapotranspiration for each meteorological station was estimated by Turc, Coutagne and Thornthwaite algorithms.

Key words: *Interpolation, Annual temperature range, Thermal continentality, Evapotranspiration, Water Framework Directive.*

Περίληψη

Η αυξημένη ζήτηση και χρήση των υδάτινων πόρων οδήγησε την Ευρωπαϊκή Ένωση στην καθιέρωση της Ευρωπαϊκής κοινοτικής Οδηγίας Πλαίσιο 2000/60 ΕΚ για τα ύδατα, η οποία έχει στόχο την καλύτερη πολιτική διαχείριση των υδάτων από τα κράτη μέλη. Προκειμένου να επιτευχθεί καλύτερη προστασία αλλά και διαχειρισή των υδάτινων πόρων, τα κράτη μέλη πρέπει να εντοπίσουνε και να αναλύσουνε τα ευρωπαϊκά ύδατα σε επίπεδο λεκάνης απορροής.

Ο υετός και η θερμοκρασία του αέρα συνδέονται άμεσα και αλληλεπιδρούν με τον υδρολογικό κύκλο και με τους υδάτινους πόρους. Ο στόχος αυτής της μελέτης είναι να *παρουσιάσει την χωρική και χρονική κατανομή του υετού και της θερμοκρασίας του αέρα στη Μακεδονία, με τη χρήση λογισμικού Γ.Σ.Π. (ArcMap 9,3).*

Τα δεδομένα που χρησιμοποιούνται είναι οι ημερήσιες, μηνιαίες και ετήσιες τιμές των παραπάνω παραμέτρων, οι οποίες ανακτήθηκαν από 82 διαφορετικούς μετεωρολογικούς σταθμούς που ανήκουν στο Υπουργείο Αγροτικής Ανάπτυξης και Τροφίμων, και αντιστοιχούν στο χρονικό διάστημα τριάντα χρόνων (1974-2004). Συγκεκριμένα 82 σταθμοί παρείχαν συνεχή δεδομένα ημερήσιου υετού ενώ 43 από τους σταθμούς παρείχαν συνεχή δεδομένα της ημερήσιας θερμοκρασίας του αέρα. Το Ετήσιο Θερμοκρασιακό Εύρος, η θερμική Ηπειρωτικότητα, η μέση ετήσια θερμοκρασία και το μέσο ετήσιο ύψος υετού υπολογίστηκαν, σε κάθε σταθμό, για τα τριάντα χρόνια της εξεταζόμενης περιόδου. Χρησιμοποιήθηκε το λογισμικό GIS (ArcMap 9.3) για την εφαρμογή μεθόδων χωρικής παρεμβολής, προκειμένου να προσδιοριστούν οι τιμές των παραπάνω παραμέτρων στη Μακεδονία. Ακολούθησε έλεγχος αξιοπιστίας των μεθόδων και η πιο αξιόπιστη μεθοδος χρησιμοποιήθηκε για την δημιουργία χαρτών με τις προαναφερόμενες παραμέτρους. Έπειτα έγινε υπολογισμός της εξατμισοδιαπνοής για όλους τους μετεωρολογικούς σταθμούς με τρεις μεθόδους Thornthwaite, Turc και Coutange.

Λέξεις κλειδιά: *Ετήσιο θερμοκρασιακό εύρος, Βαθμός θερμικής ηπειρωτικότητας, Εξατμισοδιαπνοή, Κοινοτική Οδηγία 2000/60.*

1. Introduction

Precipitation, air temperature and evapotranspiration are directly related and interacted with the water cycle. This article is part of a research, which examines the spatial and temporal distribution of the aforementioned climatic parameters in Macedonia Greece, in order to decide if these parameters should be used as one of the alternative factors of System B for Greece's river typology according to the (WFD) Water Framework Directive 2000/60 for Community action in the field of water policy. According to the WFD, Member States are obliged to classify all surface waters by one of the two typology systems, A or B. System A has fixed types with specific categorisation. System B can include alternative factors alongside with the obligatory factors of System A, but leaves to the analyst's discretion the categorisation of these factors as long as the new typology achieves at least the same level of categorisation as System A. (Kanli, 2009).

2. Parameters, Data and Method

2.1. Climatic Parameters

2.1.1. Annual Temperature Range

The annual course of temperature depends on the deviation of sun (position of sun according to earth in general), place's latitude and the respective path of solar radiation. At North hemisphere, higher temperature is observed during July or August while minimum during January or February (Zampakas, 1981). Mean annual Temperature at each station, derives by calculating the mean monthly temperature for a 30-year period and abstracting from the maximum monthly temperature the minimum monthly temperature as shown at table 2. Annual temperature range can be used to categorise the climate type in 4 different types (Supan, 1880): i) $A \leq 15^oC$ Equator climate type, ii) $15^oC < A \leq 20^oC$ Transitional maritime climate type and iii) $20^oC < A \leq 40^oC$ Continental climate type, iv) $40^oC < A$ Extreme continental climate type.

2.1.2. Parameter K of Thermal Continentality

The index of thermal continentality, parameter K, which is most often used in Europe was proposed by Gorczynski in 1918, (Mikolaskova, 2009).

Equation 1 – Gorczynski for Thermal Continentality

$K = 1{,}7(A - 12\sin\theta)/\sin\theta$ or $K = 1{,}7A/\sin\theta - 20.4$

Parameter K is the index of continentality expressed as a percent, A is annual range of temperature in °C and θ is latitude in degrees (WGS84). Expression $A=12\sin\theta$ corresponds well to observations above sea (Gorczynski, 1922), constant 1.7 is calculated from the assumption that Verchojansk, in eastern Siberia, is representative of 100% continentality. K value range is 0-100, where 0 is observed at sea locations, where climate is no longer influenced by continental surface and 100 at purely continental areas, where there is no influence from maritime air masses. This parameter is not applicable at low latitudes (Conrad and Pollak, 1950) but it is applicable in Greece. Gorczynski suggests three degrees of continentality according to parameter K value: i) $0\% \leq K \leq 33\%$ Transitional maritime climate type, ii) $33\% < K \leq 66\%$ Continental climate type and iii) $66\% < K \leq 100\%$ Extreme continental climate type.

2.1.3. Evapotranspiration

Although several variations of the definition exist, potential evapotranspiration (PET) can be generally defined as the amount of water that could evaporate and transpire from a vegetated landscape without restrictions other than the atmospheric demand (Thornthwaite, 1948; Penman, 1948; Jensen et al., 1990). Evapotranspiration (ET) is the sum of evaporation and plant transpiration from the Earth's land surface to atmosphere. To estimate ET, three methods were used in this study: Turc, Coutagne and Thornthwaite. These methods need the mean monthly and annual precipitation and the mean monthly and annual temperature.

- Turc algorithm, equation 2, for estimating ET, uses P mean annual precipitation in mm and T which is the mean annual temperature in °C.

Equation 2 – Turc algorithm for Evapotranspiration

$E= P/\sqrt{(0{,}9+P^2/L^2)}$, with $L=300+25T+0{,}05T^3$

- Coutagne algorithm, equation 3, for estimating ET is applicable when the condition $1/8\lambda \leq P \leq 1/\lambda$ is valid, P is the mean annual precipitation in meters and T is mean annual temperature in °C.

Equation 3 – Coutagne algorithm for Evapotranspiration

$E= P-\lambda P^2$, with $\lambda=1/(0{,}8+0{,}14T)$

- Thornthwaite algorithm requires latitude, daylight coefficient, soil moisture, mean monthly precipitation in mm and mean monthly temperature in °C (Palmer & Havens, 1958; Pereira & Camargo, 1989; Kerkikdes et.al., 1996; Mardikis et al., 2005; Dalezios & Bartzokas, 2009).

Equation 4 – Thornthwaite algorithm for Evapotranspiration

$PET_i(L)=K*PET_i(0)$, $PET_i(0)=1{,}6*(10T_i/J)^c$, $J=\Sigma_{i=1}^{12}(I_i)$ and $I_i=(T_i/5)^{1{,}514}$

T_i=mean i monthly temperature and $C=0{,}000000675*J^3 - 0{,}0000771*J^2 + 0{,}01792*J + 0{,}49239$

$PET_i(0)$ = Potential Evapotranspiration at 0 latitude. Constant K differs according to latitude. For our case study at all meteorological stations the same constant K values were used and these are shown at table 1.

Table 1 – Constant K values in Thornthwaite Method.

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
K	0,83	0,83	1,3	1,11	1,25	1,26	1,27	1,19	1,04	0,96	0,82	0,8

Average monthly precipitation is estimated by averaging the overall precipitation for each month for 1974-2004. Mean annual precipitation is very reliable measured at points where meteorological stations are situated and was estimated by summing the average monthly precipitation for the same period. Average monthly temperature is estimated by averaging the average temperature for each month during the period of 1974-2004. Mean annual temperature was estimated by averaging the monthly average temperature for the aforementioned period.

2.2. Studying Area and Data

Macedonia is a district of North Greece as shown at figure 1. Studying area is a polygon that includes all the watersheds of Macedonia's torrents and rivers, resulting in a polygon the boundaries of which differ from the boundaries of Macedonia's political district. The boundaries were determined BY THE Ministry of Rural Development and Food in collaboration with the Institute of Geology and Mineral Exploration and always according to the WFD guidelines for water bodies. Studying area is 36290 km^2, has a perimeter of 2163 km and includes 77 different torrents in which main rivers are divided according to WFD and the watersheds are of 3-4775 km^2.

Ministry of Rural Development and Food provided data from 82 meteorological stations, which correspond to different time periods during an eighty year period (1930-2010) and include daily, monthly and annual measurements of precipitation, while 43 of them included also daily monthly and annual measurements of temperature. In order to study the climatic parameters for a given area, a 30-year period with good spatial and temporal distribution is needed. For our studying area, after sorting the data from all 82 meteorological stations the best period corresponded to 1974-2004, as all data were daily and continuous for this period.

Table 2 – Annual Temperature Range A at each station with the minimum and maximum mean T for period 1974-2004.

Station	County	A	Minimum T	Maximum T
Ano kalliniki	Florina	21,3	2,0 Jan	23,3 July
Limnochori	Florina	19,9	2,6 Jan	22,5 July
Amuntaio	Florina	20,0	3,0 Jan	23,0 July
Tropaiouxos	Florina	20,6	1,0 Jan	21,6 july
Monospita	Imathia	20,6	4,2 Jan	24,8 July
Rodochori	Imathia	19,9	3,7 Jan	23,6 July
Exaplatanos	Pella	20,0	4,5 Jan	24,5 July
Vrontous	Pieria	19,7	5,5 Jan	24,5 July
Moschopotamos	Pieria	19,5	4,9 Jan	24,3 July
Saint Paraskevi	Grevena	19,8	3,0 Jan	22,7 July
Alatopetra	Grevena	19,2	2,2 Feb	21,5 July
Krua Vrusi	Pella	20,5	4,0 Jan	24,5 July
Plana	Chalkidiki	19,1	5,3 Jan	24,5 Aug
Ano Theodoraki	Kilkis	19,2	4,0 Jan	23,2 July
Metaxochori	Kilkis	19,4	3,4 Jan	22,8 July
Melanthio	Kilkis	19,4	3,4 Jan	22,8 July
Nea Chalkidona	Thes\niki	20,5	4,7 jan	25,2 July
Chalastra	Thes\niki	20,2	4,7 jan	24,9 July
Drama	Drama	21,0	4,1 Jan	25,1 July
Kato Nevrokopi	Drama	20,8	0,2 jan	21 July
Kalampaki	Drama	20,5	4,2 Jan	24,7 July
Argyroupoli	Drama	21,6	3,7 Jan	24,3 Aug
Leukogia	Drama	21,7	0,6 Jan	22,1 July
Prinos Thasou	Kavala	20,0	4,9 Jan	24,9 July

Data from 43 meteorological stations, of the studying area, were available to be used in order to calculate the mean monthly and annual temperature, the annual temperature range A and the parameter K of thermal continentality. The data were of different periods during 1950-2010 and of different time continuity, 12-65 years. Period 1974-2004 was chosen to be used because most stations had data for this period. After sorting the data from the meteorological stations, 32 of them had data during the aforementioned period but only 24 had continuously data for the whole period of 30 years; therefore these stations were used (Table 2).

For the mean annual precipitation analysis, over the 82 meteorological stations only 64 had continuous data for the period 1974-2004 (Table 3) and included the 24 stations that were used to calculate the annual temperature range A. As there was a big diversity in the spatial distribution of the 24 and 64 meteorological stations, it was decided that two thematic maps should be constructed, with the spatial and temporal distribution of the precipitation through Macedonia. Afterwards, these thematic maps were checked for similarities and differences (Figure 6 and 7).

Table 3 –Mean Precipitation at each station for period 1974-2004 and the geographical position in EGSA 87 (meters).

Station	County	P(mm)	Altitude	Longitude	Latitude
Ano kalliniki	Florina	521,1	634,6	284948,045	4526799,972
Limnochori	Florina	541,3	598,9	294062,520	4500615,249
Amuntaio	Florina	438,1	579,0	304125,020	4507749,929
Polypotamos	Florina	619,0	1000,0	276016,096	4510396,803
Skopos	Florina	435,7	775,0	300399,873	4526365,940
Tropaiouxos	Florina	622,7	695,0	283109,746	4512037,983
Veui	Florina	535,1	734,7	297286,337	4515340,333
Aalexandria	Imathia	690,2	750,0	367360,434	4498948,430
Monospita	Imathia	596,9	47,0	346179,189	4497504,857
Koumaria	Imathia	1020,6	700,0	344499,751	4484582,860
Rodochori	Imathia	801,2	545,0	332288,798	4507060,477
Ergochori	Imathia	643,2	107,0	347437,793	4490075,164
Trilofos	Imathia	697,2	151,5	344653,693	4491983,540
Exaplatanos	Pella	635,6	133,0	342816,284	4538298,946
Notia	Pella	446,2	590,0	348692,164	4551133,402
Theodoraki	Pella	876,7	424,0	348348,671	4534480,631
Promachonas	Pella	890,2	250,0	329206,902	4433086,364
Skydra	Pella	550,7	46,0	343710,041	4514215,579
Ktima Kastorias	Kastoria	596,0	690,0	268286,411	4488408,209
Vrontous	Pieria	850,2	180,0	352321,397	4451109,708
Kolindros	Pieria	664,2	300,0	372715,011	4482198,998
Lofos	Pieria	821,8	250,0	362285,404	4452772,325
Mosxopotamos	Pieria	775,1	516,0	356858,373	4465828,328
Trilofos	Pieria	695,9	318,0	369664,889	4469296,912
Deskati	Grevena	668,0	850,0	311867,150	4422388,357
Saint Paraskevi	Grevena	727,1	615,0	281013,000	4439877,045
Alatopetra	Grevena	857,0	1250,0	262479,391	4438582,591
Anabruta	Grevena	920,2	860,0	282381,140	4437985,969
Kariotissa	Pella	533,1	9,0	356483,832	4514111,447
Krua Vrusi	Pella	524,2	8,0	356302,515	4504740,156
Trikala	Imathia	572,1	7,0	363097,862	4497174,779
Megali Panagia	Chalkidiki	679,8	440,0	471584,641	4477471,821
Plana	Chalkidiki	550,8	11,5	471556,731	4470071,868

Ormulia	Chalkidiki	472,8	40,0	461606,877	4460865,882
Rizes	Chalkidiki	742,0	350,0	451902,804	4483187,002
Ano Theodoraki	Kilkis	495,2	480,0	415959,912	4557455,098
Metaxoxori	Kilkis	565,1	63,0	411631,530	4546402,983
Melanthio	Kilkis	618,8	490,0	419912,640	4535205,366
Nea Chalkidona	Thessaloniki	508,6	29,5	381632,419	4509811,675
Chalastra	Thessaloniki	443,1	4,0	393266,166	4535543,332
Kalamoto	Thessaloniki	787,0	220,0	446284,268	4488778,629
Mavrouda	Thessaloniki	687,0	360,0	453583,750	4516454,322
Diavata	Thessaloniki	461,3	14,0	402694,802	4505804,818
Vraxia	Thessaloniki	415,6	2,0	384332,087	4502366,704
Drama	Drama	645,5	101,0	511038,602	4555131,545
Kato Nevrokopi	Drama	725,7	580,0	488696,344	4577334,585
Nikiforos	Drama	642,1	236,0	525017,441	4557016,570
Livadero	Drama	877,5	650,0	517855,148	4625457,932
Mikropoli	Drama	934,4	360,0	484478,409	4560689,863
Kalampaki	Drama	645,2	67,3	515257,514	4544037,941
Argyroupoli	Drama	746,5	74,0	502648,896	4551423,084
Leukogia	Drama	856,5	621,4	490098,077	4582883,456
Exochi	Drama	715,0	620,0	484529,212	4584743,409
Katafygio	Drama	745,1	761,0	473359,448	4577374,373
Ochyro	Drama	1127,5	543,0	487292,487	4571786,029
Iraklia	Serres	515,9	35,0	439744,333	4559070,950
Provatas	Serres	467,5	18,0	449439,899	4546045,337
Lower Kamila	Serres	554,4	10,0	456419,478	4542300,120
Worksite Serres	Serres	523,1	56,0	460652,182	4547827,040
Eleftheroupoli	Kavala	719,7	80,0	520902,445	4529250,503
Gialochoria	Kavala	485,6	7,0	498443,104	4508869,290
Prinos Thasou	Kavala	716,7	684,0	548325,837	4510168,565
Chrysoupoli	Kavala	569,8	18,0	558736,979	4536856,957
Moustheni	Kavala	701,0	151,0	509333,916	4522296,22

The data for calculating the potential evapotranspiration at each station derived from daily data of 24 stations at 1974-2004 period that were used for the estimation of annual temperature range, thermal continentality K and mean annual precipitation. These stations and data were chosen because Turc, Coutagne and Thornthwaite methods needed the mean monthly and annual temperature and precipitation in order to calculate PET. The high resolution Digital elevation model (DEM) with 28.3x28.3 cell size was used, which was constructed from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) of NASA Terra satellite.

2.3. Method

2.3.1. Spatial Interpolation

A very basic problem in spatial analysis is interpolating a spatially continuous variable from point samples. Spatial interpolation techniques predict values for cells in raster from a limited number of sample point data. According to first law of Geography, "Everything is related to everything else, but near things are more related than distant things" (Tobler, 1970). Unknown values are predicted with a mathematical formula that uses the values measured at nearby points. There are many different spatial interpolation techniques. Some of the most commonly used interpolation methods to model spatially distribution from point data are the following three: Inverse Distance Weighting

(IDW), spline and ordinary kriging. Overall, anomalies of local scale can be adjusted without affecting the values derived from interpolation at other points on the surface (Burrough and McDonnell, 1998).

2.3.2. Inverse Distance Weighted IDW

Inverse distance weighted (IDW) is a method of interpolation that estimates cell values by averaging the values of nearby measured data points. The main logic rule behind this technique is that the cell values next to each other are most likely to have same values, so the value of the predicted cell is more influenced by the value of cells closer than those that are further away. This technique weights the points closer to the prediction location greater than those farther away, hence the name inverse distance weighted (Watson and Philip, 1985). However the main problem with this technique is that it assumes that maximum and minimum values are measured at the sampled points and all other unsampled points have values between those values.

2.3.3. Spline Interpolation

Spline is an interpolation method in which cell values are estimated using a mathematical function that minimizes overall surface curvature, resulting in a smooth surface that passes exactly through the input points. It is a deterministic, locally stochastic interpolation technique, which represents two-dimensional curves on three-dimensional surfaces (Eckstein, 1989; Hutchinson and Gessler, 1994).

2.3.4. Kriging

The aforementioned methods are known as deterministic interpolation methods because they are directly based on the surrounding measured values and use specified mathematical formulas that determine the smoothness of the resulting surface. On the other hand, kriging uses statistical models that include autocorrelation among measured points, in order to predict the values at unknown points. The most commonly applied form uses “semivariogram” among pairs of sampled points. Kriging interpolation method was developed by Matheron in 1970.

2.3.5. Validation

All data were divided in 2 groups. The first group was named “training” and content 90% of sample points while the second group was named “test” and content 10% of the sample points. Training group’s measurements were used for predicting the values of the examined variable at whole Macedonia by using the aforementioned interpolation methods. Test’s group was used to validate the results of each method.

3. Results

3.1. Annual Temperature Range

In order to predict the Annual Temperature Range at Macedonia district, 24 sample points were used and divided in two subsets; the test group had 3 sample points which were randomly chosen from the 24 with only rule to be positioned within the rest and not at the edges of the study area, while the rest 21 sample points were the training group. Each interpolation method was applied at the training group and the predictions were validated using the test group (Table 4).

Table 4 – Estimated values of Annual Temperature Range by each method.

Meteorological Stations	Measured Values	Predicted Values			
		IDW	Krigging	Spline	Polynomial
Limnochori	19,9	20,19	20,11	19,9	20,31
Exaplatanos	20	20,23	20,33	20,56	20,34
Monospita	20,6	20,35	20,08	20,06	20,22
Root Mean Square Error		0,091	0,133	0,159	0,134

The validation showed that the best method was Inverse Distance Weighting. Furthermore, a raster file with cell value of 750m was created, by using IDW method and data from all 24 meteorological stations. Two thematic maps were constructed, the first visualised the spatial distribution of annual temperature range A at Macedonia (Figure 1) and the second one (Figure 2) showing the categorization of Macedonia in two climatic types, according to A values (Supan 1880). Finally possible correlation between A and elevation was checked and R^2=0,034 meaning not significant correlation.

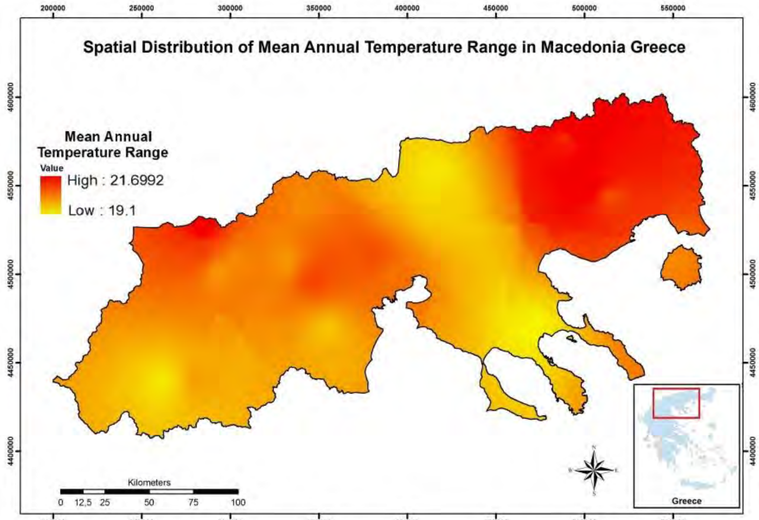

Figure 1 - Stretched map showing the gradual spatial distribution of A at Macedonia.

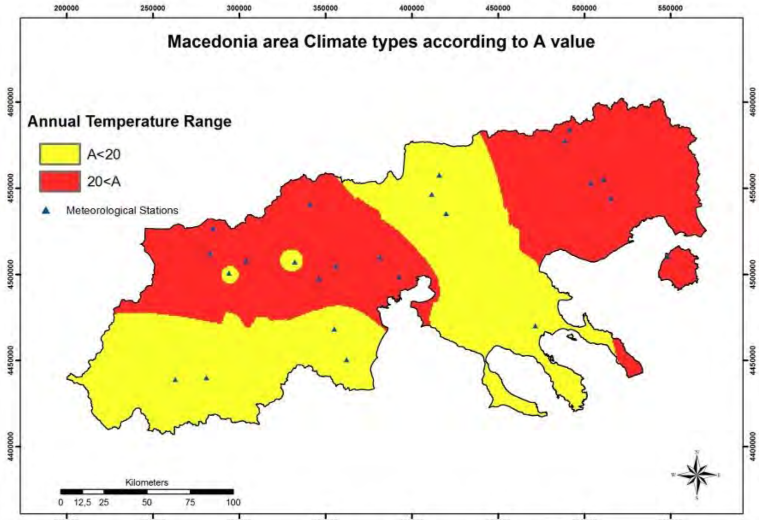

Figure 2 - Macedonia area climate types according to A value (Supan 1880).

3.2. Thermal Continentality K

Thermal continentality was constructed by applying the K algorithm at Raster calculator of ArcMap 9.3. In order to do this, two raster files of cell size 750 meters were used: one file with the annual temperature range value (the raster file thaw was previously constructed with IDW) and a second one with the latitude values per cell in WGS84. The results of the K were visualised with a stretched thematic map, where K values ranged 29,18 - 35,42. Macedonia was divided in two different climate types according to the categorization of Gorczynski (Figure 3). Finally possible correlation between K and elevation was checked and R^2=0,025 meaning not significant correlation.

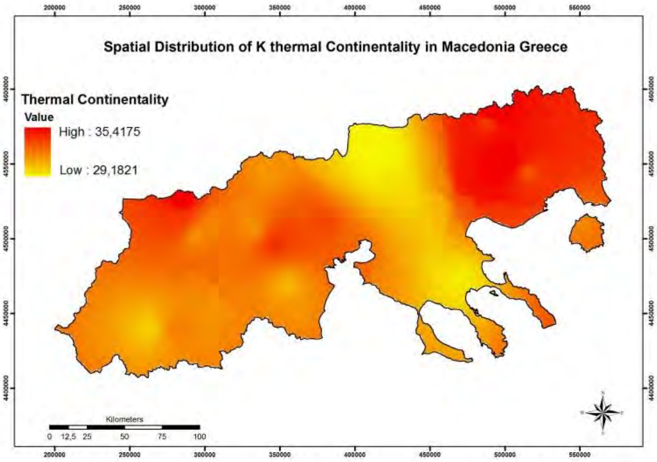

Figure 3 - Stretched map showing the gradual spatial distribution of K at Macedonia.

Mean annual temperature was estimated for each of the 24 meteorological stations that had continuous data for 1974-2004. Firstly, the mean monthly temperature for each meteorological station was calculated and then, the mean of these values gave the mean annual temperature. There is significant correlation between Mean annual Temperature and elevation where R^2 = 0,7234 as shown at Figure 4 and the corresponding equation 4 shows that the temperature declines as the elevation rises.

Equation 5 – Grimpylakos algorithm for Temperature at Macedonia

T = - 0,0038 * E + 14,904 (T is mean annual temperature and E is elevation).

The R square value (R^2), means that the mean annual temperature is 72,34% explained by elevation. Finally the equation was applied at raster calculator of ArcMap in order to estimate the temperature at the meteorological stations with no Temperature data.

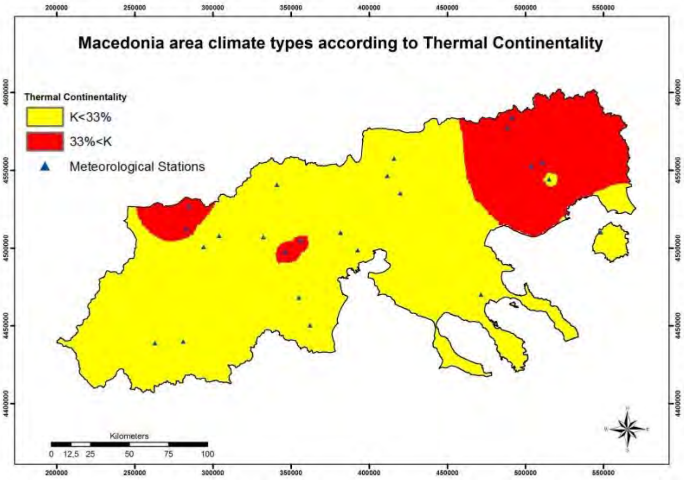

Figure 4 - Macedonia area climate types according to Thermal Continentality value.

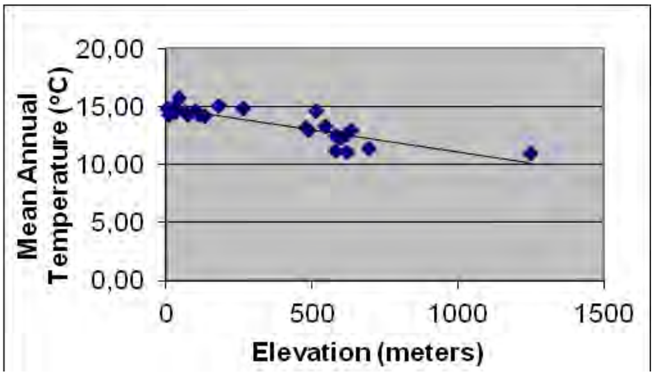

Figure 5 – Correlation of mean annual temperature with elevation.

3.3. Mean Annual Precipitation

Mean monthly precipitation was estimated for each month at all 24 and 64 meteorological stations and their total for mean annual precipitation was calculated. Two thematic maps were created showing the mean annual precipitation in Macedonia by using the interpolation method of Inverse distance weighted. The spatial distribution of the mean annual precipitation that derived from the data of 64 meteorological during 1974-2004 is projected at figure 6. The spatial distribution of the mean annual precipitation that derived from the data of 24 meteorological during 1974-2004 is projected at figure 7.The correlation between elevation and precipitation was checked with SPSS programme (Table 5). The highest possible correlation was not significant $R^2<0,21$ and so the mean annual precipitation for each cell of Macedonia could not be estimated and the corresponding thematic map using an equation between the elevation and the mean annual precipitation was not projected as it would have been inaccurate.

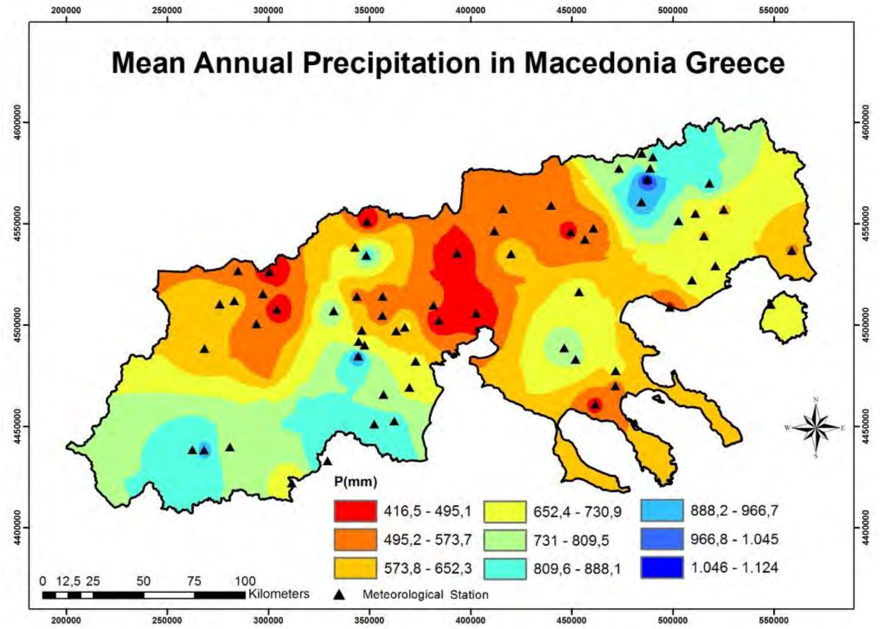

Figure 6 – Spatial distribution of mean annual precipitation at Macedonia Greece derived from 64 meteorological stations during period 1974-2004.

Table 5 – Correlation of Variables with Elevation.

Elevation	Examined Variable						
	T (°C)	P(mm)	K	A	Thornthwaite	Turc	Coutagne
Pearson	-0,851	0,306	-0,157	-0,184	0,156	-0,072	0,108
R-square	0,723	0,094	0,025	0,034	0,024	0,005	0,012

The thematic map that derived from the 24 stations missed mean annual precipitation values between 416,5 – 438,3 and 856,9 – 1124 as these data did not exist at the 24 stations. The data distribution of the 24 stations at West, central and South Macedonia is very sparse resulting in much less zones of precipitation. The map of 64 stations has good spatial distribution and is more accurate and should be used for analysis purposes.

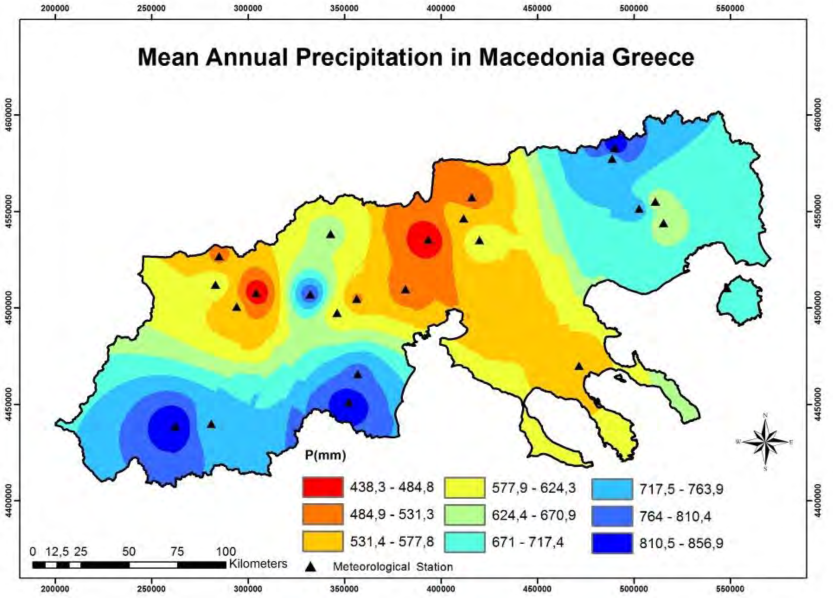

Figure 7 – Spatial distribution of mean annual precipitation at Macedonia Greece derived from 24 meteorological stations during period 1974-2004.

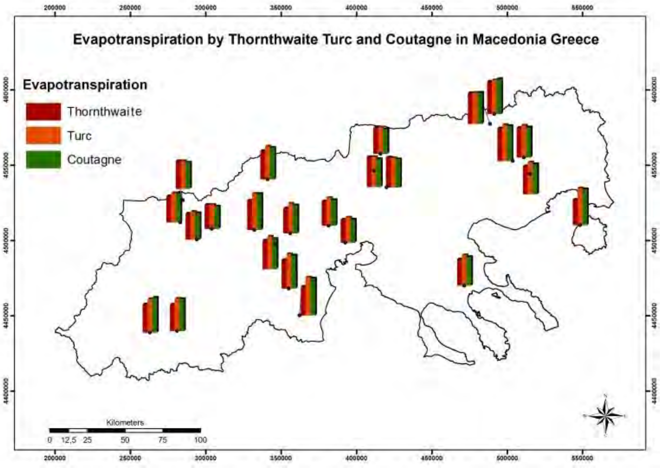

Figure 8 – Evapotranspiration in Macedonia Greece.

3.4. Evapotranspiration

Evapotranspiration was calculated with all three methods for each of the 24 stations (Figure 6). Evapotranspiration by Turc method is higher than Thornthwaite method at all stations and in 21 of 24 stations it is higher than Coutagne method, while Coutagne is higher than Thornthwaite method at 19 of 24 stations. On the other hand, Turc method is the most easily applied method of all, as Coutagne method is not always applicable and Thornthwaite's method uses parameters that differ according to elevation and the spatial distribution of each examined place, which makes it very difficult to apply this method at all stations. No significant correlation between elevation and evapotranspiration (Table 5). Finally Thornthwaite method is underestimating the evapotranspiration in comparison with the other two methods.

4. Discussion

There were small differences between predicted and measured values among the four interpolation methods that were tested for predicting A, annual temperature range, as noted also by Sailesh et al., 2012; in our case, IDW was the most accurate one as shown at table 4 as it has the smallest residuals. The spatial distribution of temperature data in central and Northwest Macedonia is very good. The estimation of annual temperature range A and thermal continentality K north of 4450000 meters and west of 525000 meters (GCS GGRS 1987) was accurate. On the other hand, the estimation of the variables, South and East of the aforementioned coordinates, needs to be crosschecked with meteorological data of nearby areas as data's spatial distribution at these areas is weak. Annual temperature range value is increasing as the distance from sea is increasing and while moving to the North (Nastos et al., 1995) as shown at figure 1a; classification by Supan (1880) divided Macedonia in two zones (figure 1b). Thermal continentality classification by Gorczynski (1922) divided Macedonia in two similar zones to A of Supan (1880) (Figure 4). From the combination of the results of A and K spatial distribution a final map was constructed and Macedonia was divided into the following three zones (Figure 7):

- $0\% \leq K \leq 33\%$ and $15^{o}C < A \leq 20^{o}C$ Transitional Maritime climate type
- $0\% \leq K \leq 33\%$ and $20^{o}C < A \leq 40^{o}C$ Transitional Continental climate type
- $15^{o}C < A \leq 20^{o}C$ and $33\% < K \leq 66\%$ Transitional Continental climate type
- $33\% < K \leq 66\%$ and $20^{o}C < A \leq 40^{o}C$ Continental climate type.

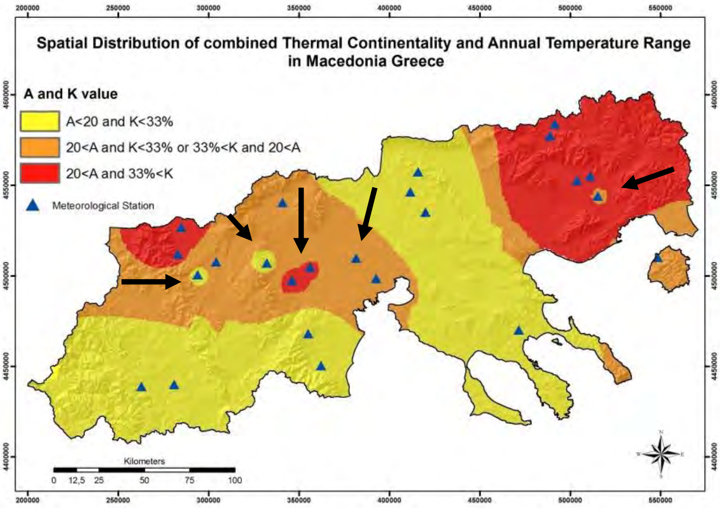

Figure 9 – Macedonia is divided in three climate types according to the author.

During the interpretation of the results as shown at figure 9, five anomalies can be observed at the map; at the two red arrows that show three stations with high A and K values, because the IDW method was not able to connect those two areas as it should have done, meaning this red small circles are not anomalies but a red zone situated Northwest of Katerini – Thessaloniki. The two yellow anomalies have A=19,9<20 classification by Supan (1880), while the orange has K=32,95% < 33%, classification by Gorczynski (1922); both cases can be included in the surrounding zone. The red arrows anomaly can be avoided with supervised classification. The elevation distribution of the meteorological stations was not adequate to check the possible correlation between Precipitation and Elevation at Macedonia and to create an equation. A map showing the spatial distribution of Evapotranspiration could not be created, as Precipitation values were necessary, that could not be precisely estimated. Mean annual precipitation, evapotranspiration and total runoff at each meteorological station were estimated and projected (Figure 10) alongside with the anaglyph. Total runoff is very strong correlated with high elevation and low temperature. Total runoff is higher at Southwest part of Macedonia west of Pindos mountain chain. The strong correlation with elevation is explained by the fact that at high elevation precipitation is higher while mean monthly and annual temperature is lower. This correlation is a proof that elevation distribution of each torrent watershed should be included in the classification of rivers typology; however in the elevation classification the relationship with the total runoff should be taken in consideration.

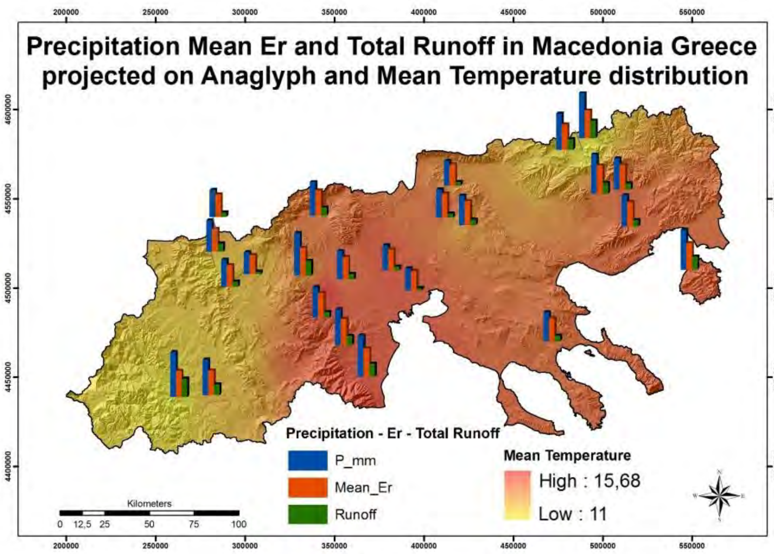

Figure 10 – Distribution of Precipitation Evapotranspiration and runoff in Macedonia Greece. On the background mean T and anaglyph is projected.

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