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RESEARCH ARTICLE **(Open Access)**

Determination of the pluviometric deficit as a base for the climate classification in Albania

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Abstract

The sum of all climatic parameters known until now, in a strict understanding, cannot be the same as climate itself. The climate is the parameters we know plus potential evapotranspiration. The purpose of this paper is first, to quantify the potential evapotranspiration and then, combining it with the rainfall values, to quantify the pluviometric deficit all over Albania as a substantial precondition for climate classification. The functions of both, potential evapotranspiration and rainfall over time, resulted to be polynomial ones, because the highest regression coefficients were found comparing with other types of functions. A correlation coefficient significant for high probability values was found between the magnitude and the duration of pluviometric deficits. The entire country, based on the findings showed, could be divided into three main areas extended from the aridity to the humidity scale. However, this preliminary basic conclusion is supposed to be verified when the pluviometric deficit quantified already, as it will be shown in this article, is going to be used for the moisture index determination, as it is indicated in the Thornthwaite's research work.

Keywords: potential evapotranspiration, rainfall, pluviometric deficit, moisture index.

1. Introduction

As it is defined early by Thornthwaite, (Thornthwaite, 1946) the climate characterization would be thorough and meaningful if the most known climate parameter as rainfall is, would be taken into consideration closely related with the potential evapotranspiration. In substance, the evapotranspiration is the inverse of the rainfall. If the rainfall brings water to the field, evapotranspiration takes the water away from the field to the atmosphere [Thornthwaite 1948, Antonio Ribeiro da Cunha et al, 2011, Pereira et al 1997]. That is why the pluviometric deficit, (defined as the change of the difference between the rainfall and evapotranspiration over time), plotted in the same coordinate system, is in fact the most straightforward and realistic mean by which the evapotranspiration can get compared with the rainfall. But, however, in spite of the fact that comparing the evapotranspiration with the rainfall is a necessary tool, classifying the climate of a country by simply using this tool is not sufficient. The opposite effects of both, evapotranspiration and rainfall, should get reflected to the soil moisture content and that is, in fact, the substance of the Thornthwaite theory, making it different from and more prevailing to the Köppen approach (Antonio Ribeiro da Cunha et al, 2011). Thornthwaite (Thornthwaite 1948, Antonio Ribeiro da Cunha et al, 2011) considered the moisture as factor truly active, using it as a basis for identifying the most of its major climatic types. That is why the Thornthwaite theory (approach) is the substance of the present paper. But, with an important change, which comes as a request of time. The potential evapotranspiration is not calculated based on the Thornthwaite model, but instead, based on the Penman – Monteith model, which is in fact a model widely recommended by FAO to be used. As it is underlined frequently, (Penman 1948, Hillel 1971a, Hillel 1982b, Hillel 2003c, Anatolij 2011) it should be noted that the advantage of the Penman-Monteith model to the potential evapotranspiration calculation is that the model is physically well based, because it comes from a "combination of the energy balance equations with the equations of vapor and heat transport (Penman 1948, Anatolij 2011). In order to clarify even more the background of the actual paper, it would be said that we look at the potential evapotranspiration and rainfall as a combination by which the climate could be characterized rather than

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the changing climate itself would affect the hydrology of a given environment (evapotranspiration, rainfall, soil moisture content, type of vegetation), which is on the focus of many other studies in our days (Soňa Něměčková 2011, Hana Hlavačikova 2013, T. Toreros et al, 2014, Alley, W.M.,1984). If the comparison of potential evapotranspiration and rainfall would be done from a quantitative point of view, it would produce the existing balance of a climate, whether it is either humid (the rainfall is greater than the evapotranspiration) or arid (the rainfall is less than the evapotranspiration). Two very important parameters can get quantified in a pluviometric deficit: the duration and the magnitude. Both of them, quantified in space and time, become very useful tools towards the climate characterization of a given area. The present study's objective is to calculate the pluviometric deficit in various locations (56 meteorologic stations) spread throughout Albania over years. The pluviometric deficit quantified as it is presented in this article, is going to become a very secure foundation by which the moisture index itself, as it is foreseen in the Thornthwaite approach, could get calculated, and consequently, the country's climate could be characterized.

2. Material and Methods

The method applied to quantify the pluviometric deficit in 56 six meteorological stations throughout Albania is rather complex and involves three stages.

2.1 Applying Penman-Monteith formulae to quantify the potential evapotranspiration.

The Penman-Monteith formulae, as it is recommended by FAO, was applied to determine the potential evapotranspiration (Richard G. Allen, et al., 1998, Gjongecaj B., et al, 2012) for each meteorological station under consideration. Temperature, sun radiation, wind speed and relative humidity are measured on daily basis for a period of ten years.

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \qquad (1);$$

where:

ET_o is potential evapotranspiration, mm/day,
R_n is net sun radiation, MJoul/m^2 day,
G is density of the heat flux from the soil to the atmosphere, MJoul/m^2 day,
T is the air temperature at 2m height, °C,
u_2 is the wind speed at 2m height, m/sec,
e_s saturated vapor pressure, kPascal,
e_a actual vapor pressure, kPascal,
e_s - e_a vapor pressure deficit, kPascal,
Δ slope of curve vapor pressure-air temperature,
γ psychrometric constant, kPascal/°C.

To do the calculations, the computer programme released by FAO was used.

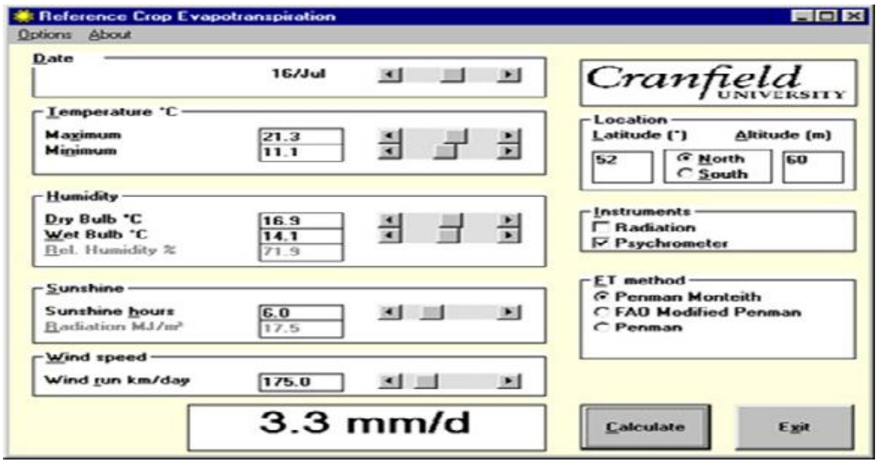

Figure 1: The FAO software to calculate the potential evapotranspiration as a result of the data on temperature, relative humidity, wind speed and sun radiation following the Penman-Monteith formulae.

2.2 Determination of rainfall

Determination of the rainfall has been done at the same time as the potential evapotranspiration was. The rainfall readings were done in a classic manner.

2.3 Pluviometric deficit determination

The regression analysis was done in order to determine the ET_p functions over time and the R functions over time. The respective functions were plotted in the respective graphs, accompanied by the respective equations and determination coefficients (R^2). The following map presents the locations spread throughout the country.

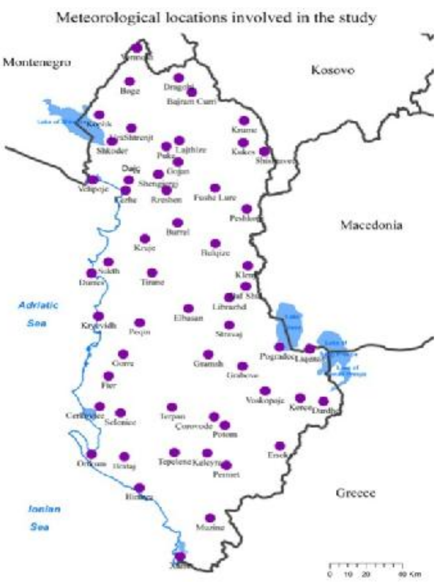

Figure 2: The locations of meteorological stations spread throughout the country

2.4 Determination of the duration and magnitude of the pluviometric deficit for each meteorological station in consideration.

Duration of the pluviometric deficit was determined equalizing the regression equations found for both: potential evapotranspiration over time [$ET_p=f_1(time)$] and rainfall over time [$R=f_2(time)$], so, the intersected points of the curves were calculated based on the solution of the following equity:

$ET_p = R$ or $f_1(time)= f_2(time)$

Magnitude of the pluviometric deficit was determined by the difference between the defined integrals of $ET_p=f_1(time)$ with $R=f_2(time)$ where the boundaries of integration were the time of pluviometric deficit beginning (t_1) and the time of pluviometric deficit ending (t_2), following the downwritten model:

$$\int_{t_1}^{t_2}(a_1t^2+b_1t+c_1)dt-\int_{t_1}^{t_2}(a_2t^2+b_2t+c_2)dt = \int_{t_1}^{t_2}(at^2+bt+c)dt = \left(\frac{at^3}{3}+\frac{bt^2}{2}+ct\right)\Big|_{t_1}^{t_2} \quad (2)$$

where a_1, b_1, c_1, a_2, b_2, c_2, are the coefficients found in the regression analysis where $ET_p=f_1(time)$ and $R=f_2(time)$ were determined. This part of the method could be illustrated by the following figure:

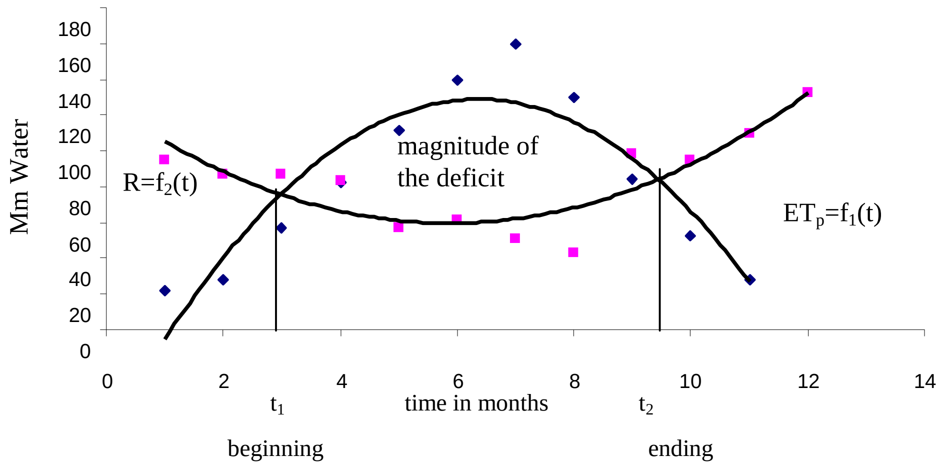

Figure 3: The conceptualized magnitude and duration of the pluviometric deficit (methodically).

3. Results and Discussion

Application of the method already described, produced these results: **a.** the curves of $ET_p=f_1(time)$ and $R=f_2(time)$; **b.** the duration of pluviometric deficit for each location taken into consideration (t_2-t_1=Δt or duration); **c.** the magnitude of pluviometric deficit for each location considered (area between two curves limited by the respective times t_2 and t_1). All of these results are presented respectively in the tables 1 and 2.

Table. 1. The functions $ET_p=f_1(time)$ and $R=f_2(time)$ and the respective coefficients of regression for 56 meteorological locations throughout Albania

Nr	Location	ETp=f1(time)	R^2	R=f2(time)	R^2
1	B. Curri	$ETp = -4.06t^2 + 52.91t - 52.49$	0.84	$R = 4.20t^2 - 60t + 296.41$	0.84
2	Bogë	$ETp = -3.65t^2 + 47.88t - 48.77$	0.84	$R = 7.38t^2 - 90.2t + 401.85$	0.74
3	Brataj	$ETp = -4.12t^2 + 53.97t - 44.57$	0.85	$R = 8.18t^2 -101.14t+396.21$	0.88
4	Bulqizë	$ETp = -3.90t^2 + 50.96t - 50.82$	0.84	$R = 1.67t^2 - 20.49t +122.99$	0.70
5	Burrel	$ETp = -3.88t^2 + 50.57t - 47.38$	0.77	$R = 2.54t^2 - 34.07t +178.76$	0.79
6	Cerkovicë	$ETp = -4.38t^2 + 57.56t - 49.52$	0.83	$R = 5.53t^2 - 66.27t +265.26$	0.85
7	Çorovodë	$ETp = -4.16t^2 + 54.06t - 50.06$	0.85	$R = 1.93t^2 - 22.64t +126.02$	0.77
8	Dajç-Zad.	$ETp = -4.14t^2 + 53.87t - 49.12$	0.84	$R = 3.60t^2 - 46.09t +223.54$	0.66
9	Dardhë	$ETp = -3.77t^2 + 49.28t - 49.01$	0.84	$R = 2.03t^2 - 23.14t +118.66$	0.86
10	Dragobi	$ETp = -3.95t^2 + 51.51t - 53.19$	0.84	$R = 9.40t^2 - 15.32t +522.62$	0.84
11	Durrës	$ETp = -4.27t^2 + 55.62t - 47.14$	0.85	$R = 2.69t^2 - 31.88t +138.46$	0.78
12	Elbasan	$ETp = -4.17t^2 + 54.27t - 48.31$	0.84	$R = 2.58t^2 - 33.40t +151.38$	0.82
13	Ersekë	$ETp = -3.66t^2 + 48.33t - 45.84$	0.85	$R = 2.78t^2 - 36.06t +163.23$	0.63
14	Fier	$ETp = -4.41t^2 + 57.61t - 53.44$	0.85	$R = 2.14t^2 - 25.50t +108.24$	0.70
15	F-Lurë	$ETp = -3.71t^2 + 48.42t - 49.32$	0.83	$R = 3.10t^2 - 38.86t +216.38$	0.64
16	Gojan	$ETp = -4.02t^2 + 52.57t - 51.86$	0.83	$R = 4.52t^2 - 57.90t +337.64$	0.63
17	Gorre	$ETp = -4.37t^2 + 57.15t - 51.56$	0.85	$R = 1.79t^2 - 20.72t +120.53$	0.66
18	Grabovë	$ETp = -3.98t^2 + 51.95t - 50.78$	0.84	$R = 2t^2 - 31.19t + 171.21$	0.75
19	Gramsh	$ETp = -4.03t^2 + 52.43t - 46.58$	0.85	$R = 1.21t^2 - 11.89t + 82.27$	0.79
20	Himarë	$ETp = -3.96t^2 + 51.93t - 42.42$	0.84	$R = 4.46t^2 - 51.09t +186.71$	0.90
21	Këlcyrë	$ETp = -4.30t^2 + 56.26t - 48.19$	0.84	$R = 3.68t^2 - 44.44t +192.73$	0.67
22	Klenjë	$ETp = -3.78t^2 + 49.48t - 48.01$	0.86	$R = 3.70t^2 - 45.41t +206.99$	0.78
23	Koplik	$ETp = -4.25t^2 + 55.62t - 50.41$	0.84	$R = 3.99t^2 - 48.61t +231.24$	0.69
24	Korçë	$ETp = -4.075t^2 +53.41t -50.62$	0.84	$R = 3.67t^2 - 47.38t + 193.1$	0.91
25	Krujë	$ETp = -4.11t^2 + 54.14t - 52.94$	0.83	$R = 4.75t^2 - 60.58t +262.58$	0.67
26	Krumë	$ETp = -4.14t^2 + 54.15t - 51.51$	0.85	$R = 2.14t^2 - 25.76t +147.83$	0.71
27	Kryevidh	$ETp = -4.36t^2 + 57.14t - 49.89$	0.85	$R = 2.35t^2 - 26.71t +127.49$	0.76
28	Kukës	$ETp = -4.23t^2 + 55.48t - 54.16$	0.84	$R = 2.27t^2 - 26.31t + 132.4$	0.86
29	Lajthizë	$ETp = -4.00t^2 + 52.42t - 51.75$	0.85	$R = 3.96t^2 - 48.22t +229.37$	0.82
30	Lezhë	$ETp = -4.22t^2 + 55.18t- 45.60$	0.85	$R = 2.71t^2 - 30.89t +171.24$	0.74
31	Librazhd	$ETp = -3.98t^2 + 52.1t - 43.62$	0.85	$R= 2.55t^2 - 31.47t + 169.04$	0.74
32	Liqenas	$ETp = -3.92t^2 + 51.43t - 47.70$	0.84	$R = 1.84t^2 - 20.62t +112.27$	0.61
33	Muzinë	$ETp = -4.25t^2 + 55.88t - 49.69$	0.84	$R = 4.42t^2 - 51.78t +211.94$	069
34	Orikum	$ETp = -3.86t^2 + 50.61t - 35.08$	0.84	$R = 4.52t^2 - 51.07t +192.71$	0.84
35	Peqin	$ETp = -4.16t^2 + 54.02t - 41.55$	0.87	$R = 1.70t^2 - 25.61t +133.94$	0.70
36	Përmet	$ETp = -4.40t^2 + 57.29t - 49.42$	0.84	$R = 3.12t^2 - 36.82t +161.02$	0.77
37	Peshkopi	$ETp = -3.86t^2 + 50.86t - 50.81$	0.85	$R = 1.20t^2 - 27.70t +150.68$	0.63
38	Pogradec	$ETp = -3.90t^2 + 50.9t - 47.17$	0.84	$R = 3.07t^2 - 35.87t + 169.1$	0.74
39	Potom	$ETp = -3.79t^2 + 48.90t - 34.24$	0.80	$R = 2.19t^2 - 24.84t +129.44$	0.61
40	Pukë	$ETp = -3.80t^2 + 49.84t - 47.88$	0.84	$R = 3.77t^2 - 44.25t +223.94$	0.68
41	Qaf-Shul	$ETp = -3.76t^2 + 49.28t - 42.78$	0.86	$R = 3.38t^2 - 41.47t +193.32$	0.88
42	Rrëshen	$ETp = -3.92t^2 + 51.27t - 44.15$	0.84	$R = 3.36t^2 - 40.2t + 228.14$	0.65
43	Selenicë	$ETp = -4.24t^2 + 55.40t - 41.42$	0.85	$R = 2.22t^2 - 25.89t +124.45$	0.86
44	Shëngjergj	$ETp = -3.91t^2 + 51.27t - 51.48$	0.83	$R = 3.14t^2 - 39.29t +206.74$	0.61
45	Shishtavec	$ETp = -3.73t^2 + 48.99t - 48.45$	0.84	$R = 2.80t^2 - 35.24t + 167.4$	0.76
46	Shkodër	$ETp = -4.34t^2 + 56.90t - 56.45$	0.85	$R = 4.28t^2 - 53.39t +288.45$	0.68
47	Stavraj	$ETp = -4.02t^2 + 52.37t - 50.91$	0.86	$R = 3.05t^2 - 39.57 + 208.13$	0.63
48	Sukth	$ETp = -4.17t^2 + 54.56t - 51.71$	0.85	$R = 2.14t^2 - 25.93t + 148.7$	0.65
49	Tepelenë	$ETp = -4.38t^2 + 57.30t - 54.09$	0.84	$R = 3.95t^2 - 47.20t +211.76$	0.64
50	Tërpan	$ETp = -4.18t^2 + 54.62t - 52.62$	0.85	$R = 2.42t^2 - 32.08t +162.57$	0.67
51	Tiranë	$ETp = -4.34t^2 + 56.62t - 55.19$	0.86	$R = 1.74t^2 - 21.76t +137.69$	0.61
52	U.shtrenjt	$ETp = -4.18t^2 + 54.35t - 48.55$	0.85	$R = 4.81t^2 - 58.31t + 291.5$	0.69
53	Velipojë	$ETp = -4.27t^2 + 55.76t - 49.06$	0.84	$R = 3.58t^2 - 45.11t +234.72$	0.79
54	Vermosh	$ETp = -3.68t^2 + 48.14t - 46.72$	0.84	$R = 4.09t^2 - 46.47t +226.78$	0.62
55	Voskopojë	$ETp = -3.65t^2 + 47.76t - 43.70$	0.84	$R = 1.72t^2 - 21.11t +114.91$	0.65
56	Xarrë	$ETp = -4.07t^2 + 53.36t - 38.98$	0.84	$R = 5.01t^2 - 56.46t +217.18$	0.84

Table 2. Duration and magnitude of the pluviometric deficit in each of 56 meteorological locations throughout Albania.

Nr	Location	Beginning of pluviometric deficit t_1	Ending of pluviometric deficit t_2	Duration of the deficit pluviometric days (t_2-t_1)	Magnitude of the deficit pluviometric mm water
1	B.Curri	4.72	8.94	126.6	274.318
2	Bogë	0.00	0.00	0.00	0.00
3	Brataj	4.33	8.28	118.5	126.985
4	Bulqizë	3.26	9.59	189.9	43.47882
5	Burrel	3.72	9.49	172.8	204.8789
6	Cerkovicë	3.55	8.95	162.0	260.1455
7	Çorovodë	3.02	9.58	196.8	286.7565
8	Dajç-Zadrimë	3.91	9.01	153.0	170.3567
9	Dardhë	3.07	9.88	204.3	246.7
10	Dragobi	0.00	0.00	0.00	0.00
11	Durrës	2.70	9.88	215.4	428.7894
12	Elbasan	2.95	10.03	212.4	400.6295
13	Ersekë	3.32	9.79	194.1	291.2889
14	Fier	2.40	10.29	236.7	536.1319
15	Fushë-Lurë	4.97	7.85	86.4	26.88332
16	Gojan	0.00	0.00	0.00	0.00
17	Gorre	2.85	9.79	208.2	342.2247
18	Grabovë	3.52	10.56	219.3	347.9486
19	Grmash	2.52	9.76	217.2	331.6205
20	Himarë	2.92	9.32	192.0	366.6246
21	Kelcyrë	3.21	9.41	186.0	316.9577
22	Klenjë	3.87	8.82	148.5	151.3542
23	Koplik	3.91	8.74	144.9	154.4609
24	Korçë	3.21	9.82	198.3	372.0288
25	Krujë	3.96	8.98	150.6	186.9359
26	Krumë	3.41	9.30	176.7	214.693
27	Kryevidh	2.70	9.79	212.7	399.762
28	Kukës	2.99	9.58	197.7	309.9168
29	Lajthizë	4.17	8.48	129.3	106.3203
30	Lezhë	3.51	8.92	162.3	182.1288
31	Librazhd	3.50	9.32	174.0	213.6413
32	Liqenas	2.89	9.62	201.9	292.7228
33	Muzinë	3.32	9.10	173.4	279.2127
34	Orikum	2.96	9.17	186.3	334.3417
35	Peqin	2.77	10.82	241.5	510.718
36	Përmet	2.91	9.61	201.0	375.9344
37	Peshkopi	3.46	9.95	194.7	267.7156
38	Pogradec	3.45	9.00	166.5	198.9514
39	Potom	2.90	9.45	196.5	279.1512
40	Pukë	4.57	7.85	98.4	44.29752
41	Qafe-Shul	3.65	9.05	162.0	187.755
42	Rrëshen	4.84	7.73	86.7	29.17387
43	Selenicë	2.56	10.02	223.8	446.0609
44	Shëngjergj	4.28	8.56	128.4	92.3931
45	Shishtavec	3.53	9.37	175.2	217.188
46	Shkoder	5.44	7.35	57.3	9.883191
47	Stravraj	4.13	8.88	142.5	126.1563
48	Sukth	3.39	9.36	179.1	223.5087
49	Tepelenë	3.55	9.00	163.5	224.8542
50	Tërpan	3.32	9.81	194.7	300.8089
51	Tiranë	3.31	9.58	188.1	250.0232
52	Ura e shtrenjt	5.07	7.47	72.0	20.71827
53	Velipojë	4.16	8.70	136.2	122.3082
54	Vermosh	4.72	7.46	82.2	26.69952
55	Voskopjë	3.01	9.83	204.6	283.7209
56	Xarrë	3.15	8.95	174.0	293.7133

Concerning to the curves, it can be seen that the best fit for describing them quantitatively is a polynomial function, which is picked as such because of providing the highest coefficient of determination, R^2, in comparison with other types of functions. The duration and the magnitude of the pluviometric deficit vary in space, however, three very different and representative typical curves can be noticed. The first type can be described as curves that practically do not represent any pluviometric deficit, namely, the curves which do not intersect, so, the curves representing those locations where there is no pluviometric deficit (duration and magnitude equal approximately to zero). The figure 4, belonging to the location named Dragobi, represents this situation.

In general, the north-west part of the country can be characterized as a region with a lack or very low pluviometric deficit. The second type can be described as curves that do represent a pluviometric deficit which can be characterized as a moderate one.

Figure 5, belonging to the Cerkovine location, represents this situation. The pluviometric deficit will be characterized as one that have a duration of around 150 days and a magnitude around 150-250 mm water. The third type can be described as curves that do represent a pluviometric deficit which can be characterized as a large one. The figure 6, belonging to the Peqin location, represents this situation.

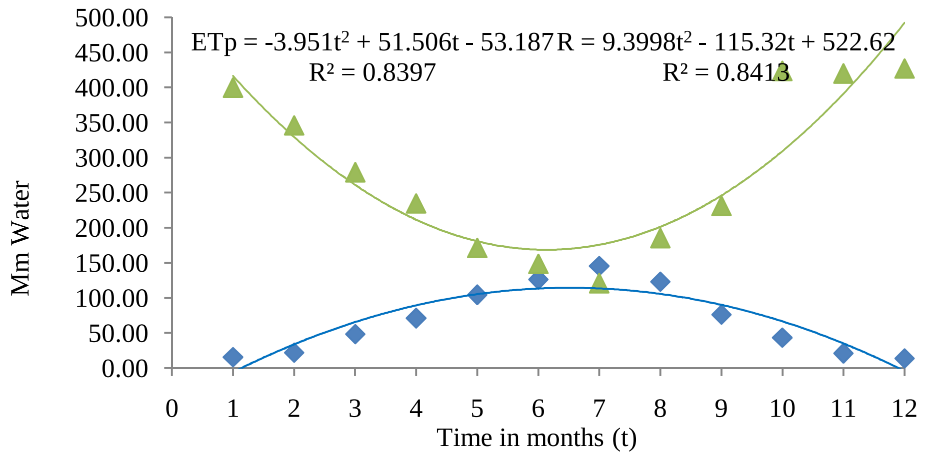

Figure 4: Pluviometric deficit belonging to the Dragobi location, north-west of Albania.

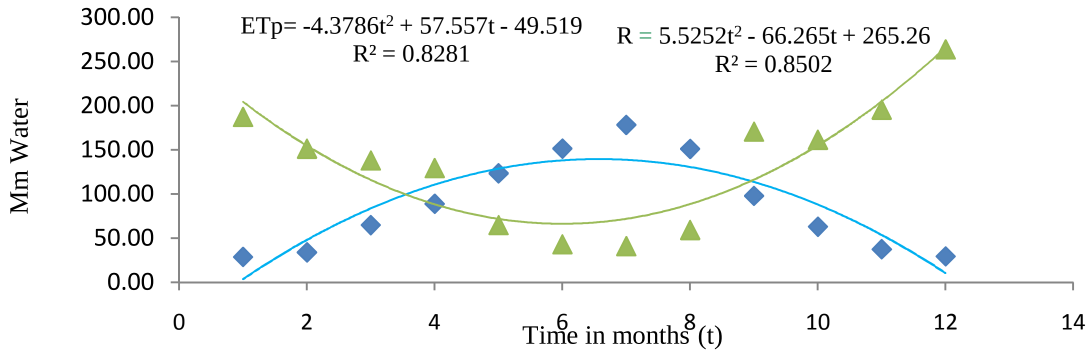

Figure 5: Pluviometric deficit belonging to the Cerkovice location, south east of Albania.

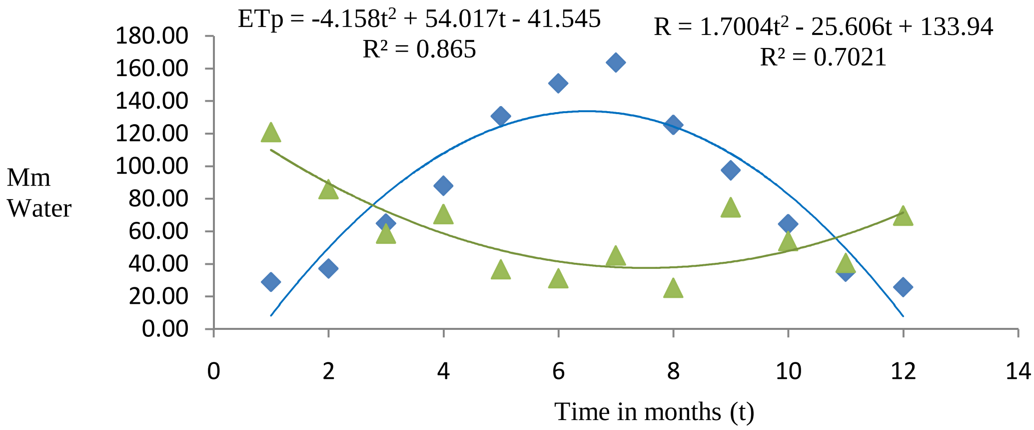

Figure 6: Pluviometric deficit belonging to the Peqin location, center of Albania.

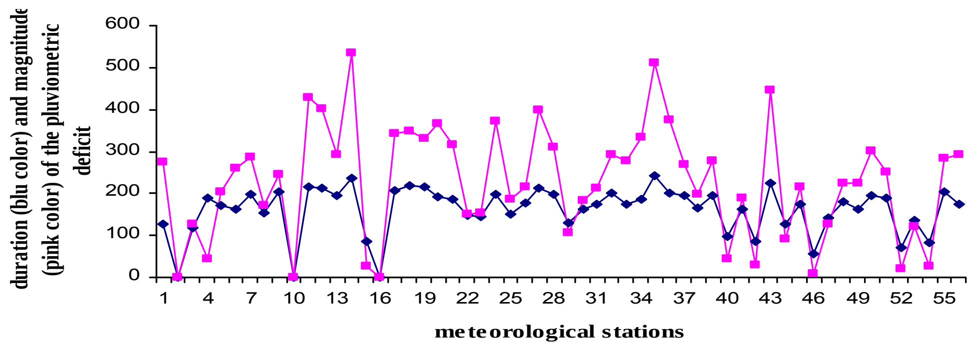

Figure 7. A graphical presentation of the duration and the magnitude of pluviometric deficit in space. Both, the magnitude and the duration of pluviometric deficit are correlated as the coefficient of correlation between them is r = 0.87***.

The pluviometric deficit will be characterized as one that have a duration of around 200 days and a magnitude of even greater than 500 mm water. It is very interesting to have a look at the possibility whether there is or there isn't a statistical relation or a correlation between the duration and the magnitude of pluviometric deficit. The correlation does exist and it is represented by r = 0.87***, which indicates clearly that a large magnitude of pluviometric deficit cannot be developed without a last longing period of its existence and vice versa. Figure 7 describes this situation.

4. Conclusions

- The method applied to identify the pluviometric deficit in magnitude and duration is well based statistically and fits with the reality of the country over the time and space.
- The results of this study justify the split of the country area into three very different regions from the point of view of magnitude and duration of the pluviometric deficit.
- A strong correlation between the duration and the magnitude of the pluviometric deficit is proved.
- The results of this study are going to become a solid foundation towards the classification of the climate of various zones within Albania from the humidity and aridity point of views.

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