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AN ANALYSIS OF VERY DRY AND WET MONTHS OCCURRENCE PROBABILITY IN THE GROWING SEASON FOR BRASOV AREA

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Abstract: *The paper presents an analysis of the monthly aridity indices variability, for the growing season period in Brasov area, determining the probabilities for the occurrence of individual monthly values indicating very dry or wet months (from extremely dry to excessively wet). The average values of the aridity indexes indicate a climate with enough humidity, but by analysing the monthly charts, with the probabilities for different values in individual years, it occurs that dry months are quite frequent. In the study area, one should expect a month with water deficit once every three years and even very dry or extremely dry months could occur. Very wet or excessively humid months have also considerable chances to be recorded. The aridity indices calculated using data downscaled for Brasov region for the A2 and B2 climate change scenarios show important differences: considerable water deficit in March, April, May and September, and excessively wet June and August. Using the probabilities associated to certain aridity index values one could estimate the risk of damages in a forest plantation or the possible requirements of irrigations in a nursery, consequently having a better support in the decision making process.*

Key words: *aridity index, dry-wet months, probabilities, climate change.*

1. Introduction

Climate plays an important role in our lives and affects almost all sectors of human activity. Examples could be extremely diverse, the type of clothes we wear in a certain period of the year, the need of electric power for heating and cooling, the development strategies for certain regions all depend on the climate conditions [1, 15].

For the sustainable management of natural resources generally and particularly of forest resources a detailed study of climate parameters is a prerequisite. Forest ecosystems are influenced by climate conditions in a continuous manner, thus for an accurate analysis of this interaction one should consider along with the averages at least the standard deviations and ideally the frequencies of certain values. The solely use of averages in characterising the

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climate could be confusing, because at one moment in time the climate parameters could have considerably different values, given their intrinsic variability.

Water deficit or aridity often occurs in some climate regions [14], but it could be also recorded for shorter intervals in areas where the average parameters indicate enough humidity. Climate changes would probably determine the extension of arid regions and longer dry intervals, which could also appear in mountain regions [5], particularly enhanced on steep southern slopes, where local forest ecosystems and especially sensitive tree species could be affected [17].

This paper presents an analysis of the monthly aridity indices variability for the growing season period in a normally wet region (as indicated by climate averages), determining the probabilities for the occurrence of individual monthly values indicating various water supplies (from extremely dry to excessively wet).

2. Material and Methods

The region taken into consideration in this study is that of Brasov, located in central Romania, south-eastern Transilvania. This area is situated at an altitude about 600 meters at the bottom of the Postavaru Mountains.

The climate data used in this study were measured at the former weather station Brasov Prund, for a period of twenty years, spanning from 1985 to 2004, available from the database of the Forest Climatology Laboratory of the Silviculture and Forest Engineering Faculty, Transilvania University of Brasov. An important observation refers to the position of this weather station located in a valley where wind is less frequent and consequently the rainfall amounts collected by the rain gauge are higher than those measured in a wind exposed position.

In this study there were considered seven spring, summer and early autumn months: March, April, May, June, July, August and September. For determining the dry and wet months the monthly de Martonne aridity index was used [7]. This was calculated, using the simple and widely known formula, by dividing the monthly rainfall amount (in mm) multiplied by 12 to the mean temperature (in ^{o}C) plus 10. Values under 30 signal a water deficit, while very dry and extremely dry conditions are indicated by values below 20 and 10 respectively. An aridity index over 30 indicates a climate with enough humidity for forests and higher values indicate moderately humid (up to 40), very humid (50-60) or excessively humid (over 60) conditions. These thresholds were considered for the study region, based on the climate classification limits [14, 17], the bioclimatic sectors and the de Martonne aridity index values distribution over Romania [10]. The average values (1985-2004) of the de Martonne aridity index values for the study months are presented in Table 1.

For analysing the probability of dry or wet month occurrence, as indicated by the de Martonne index values, the quantile plot or the empirical distribution chart method was used, which is a simple empirical procedure, much more easily to apply than the rigorous statistical methods. According to this method, the cumulative probabilities (or plotting positions) are calculated as simple functions of the value rank in the sorted

series and the total number of observations [9, 16]. In this study, the empirical probabilities were calculated by dividing the rank index (in the descending sorted data set) by the number of observations supplemented by one [11, 13] and the results were multiplied by 100 for obtaining percent values (chances of exceeding the threshold in a century) and finally were plotted against the corresponding aridity indices values. In all these charts included in the paper, on the horizontal axes are marked cumulative probabilities (expressed in %) for values equal or greater than the aridity indices marked on the vertical axis.

Table 1

Average values of the de Martonne aridity index for the study months

	Months						
	March	April	May	June	July	August	September
Mean index values	47.9	42.2	46.2	47.1	45.24	37.5	39.9

For comparing the present situation with possible changes in the climate, there were taken into account the monthly de Martonne indices calculated for the data statistically downscaled for Brasov area (using the Statistical Downscaling Model –SDSM) for 2020-2050, considering two climate change scenarios A2 and B2 [12, 18].

3. Results

At Brasov, March is a wet month as indicated by the mean value of the aridity index for the twenty years interval that equals 47.9, but the analysis of the quantile plot chart (Figure 1a) reveals that dry or even very dry months could occur. The probability to have a March with sufficient precipitation (an aridity index over 30) is about 62%. It means that there are more than a third chances to have water deficit in March, in other words one should expect such a situation every 3 years. As observable in the chart, the probability to have a de Martonne index with a value under 20 equals 20%, that means a return period of 5 years.

The probability of an excessively humid March (with the aridity index over 60) is 33%, one in three years.

The data downscaled for this region by using SDSM for the A2 and B2 climate change scenarios show that March would be a month with a dramatic decrease in the rainfall amount and consequently the average values of the aridity index, for 2020-2050, are very low, 7.9 and 7.5 respectively, which have less than 5% chances to occur in particular years in the current conditions. Such a change would have a high negative impact on the afforestation works that are presently concentrated in this period.

In April the average value of the aridity index is 42.2, also indicating a humid period but the inter-annual variability is lower than in March as indicated by the standard deviation of 18.9 as compared with 30 for the previous month. On the chart with the estimated cumulative probabilities, presented in Figure 1b, one could note that the chance to have a month with an aridity index over 30 is about 57% but it increases to 87% for a slightly lower value of 28, meaning that a dry April is very unlikely. The probability of

an excessively humid month is 20%, lower than in March. For the A2 and B2 scenarios the index values of 15 and 16.5 fall outside the present range.

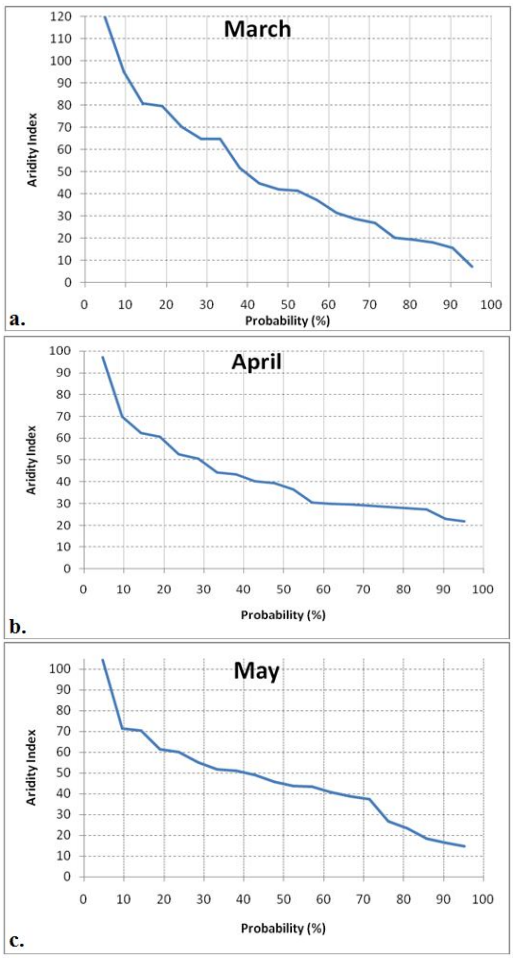

Fig. 1. Cumulative probabilities for aridity indices values in March (a), April (b) and May (c)

In May the average values are indicating enough precipitations (average de Martonne index 46.2) but, as shown in Figure 1c, there are more than 25% chances to have a moderate water deficit (an index below 30) and every 6 years one could expect to have a very dry May (an index below 20). There are good chances (70%) to have a wet May, with an aridity index greater than 39, while values over 50 are expected in four years of each decade (40%). Values between 15 and 16, as determined for the A2 and B2 scenarios, have presently less than 10% chances to occur.

In this climate region, June is the month with the highest rainfall amounts but an important inter annual variability of the aridity index could be observed in Figure 2a. In this normally wet month, a water deficit could be more frequent than one would expect, the chances to have an aridity index below 30 are about 33% (one in three years) and even values under 20 could be expected twice in a decade. There are over 50% chances to have a very humid June (with an index greater than 49) while an excessively wet month (over 60) could occur once every three years.

For June, the downscaled data for the A2 and B2 show a rainfall increase and the mean aridity indexes (for 2020-2050) are 68 and 72, indicating excessive humidity, and in the present situation the chances to have values greater than those are reduced to 15% and 8% respectively.

July is also a wet month in the study region, the average rainfall amount (104.4 mm) is slightly lower than in June (106.9 mm) and the chart in Figure 2b indicates a reduced variability as compared with the previous month. The probability of a July with enough water (aridity index over 30) is more than 70% and the chances for a very dry month are less than 5%.

For determining more accurately the chances of a very humid month (index over 50), taking into account the nearby "plateau" (at 52) a polynomial adjusted curve was added to the graph (dashed line) and using this one could infer a 40% probability for a very wet July.

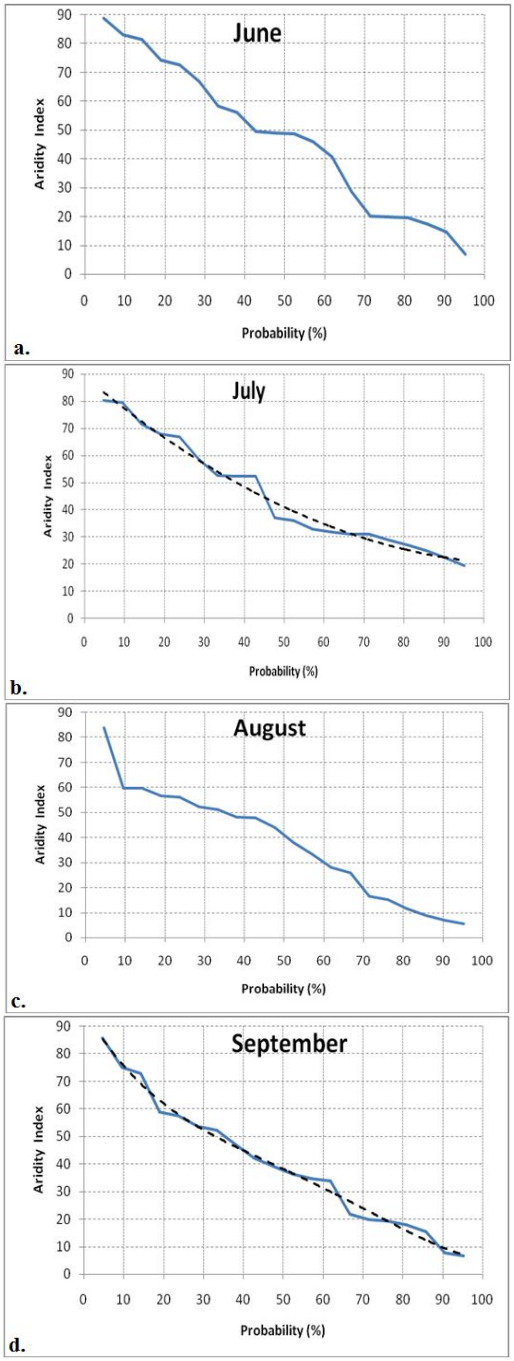

Fig. 2. Quantile plots of aridity indices for June (a), July (b), August (c) and September (d)

The values calculated for the A2 and B2 scenarios are 38.6 and 30.9, which correspond to exceeding probabilities between 50% and 60%, thus July would be quite similar.

August is drier, in Brasov, than the previous two months, with a mean aridity index of 37.5 and a higher variability from one year to another as could be observed in Figure 2c. The chances of having a water deficit are about 40% (60% probability for an aridity index greater than 30), in three years of a decade the aridity index could drop below 20 and extremely dry months (values under 10) could also occur. On the other side the chances of a very wet August (an aridity index over 50) are of approximately 35%. For August the aridity indices calculated with the data downscaled for the A2 and B2 scenarios (indicating a considerable increase in the rainfall amounts) have very high values, 82.4 and 70.4, with extremely low chances (under 7%) of being attained in the present climate conditions. This situation appears to be similar with the one forecasted for June, but most probably in August (given the high rainfall variability) the increased total amount would be produced by several very intense storms.

At Brasov, September is in average slightly wetter than August (as indicated by the mean aridity index of 39.9) but the chances of a water deficit are similar (Figure 2d), about 37% (or 40% if considering the polynomially adjusted curve marked with dashed line). Extremely dry Septembers (with aridity indices below 10) could be expected once every ten years, while the probability of values under 20 could be estimated to 22%. The probability of a very wet month (over 50) could be predicted at 35% and that of an excessively wet September(over 60) at about 20%. In September, the data for the

A2 and B2 scenarios show an increased aridity , similar with that in the spring months, the values of the aridity index being 16.9 and 17.8. In present conditions the probability of values lower than those is reduced to about 15%.

4. Discussion

The study of the de Martonne aridity index values, for each month, show a pronounced inter-annual variability. This is most probable caused by the climate variability (fluctuations) than by a climate change trend. There are several studies of the de Martonne index time series for other regions, in this part of the continent, that have not identified significant trends. In southern and eastern part of Romania the majority of the trends of the aridity indices datasets “are not statistically significant” [6] and in Vojvodina (Serbia) “there are no aridity trends” [8]. Certainly this is an area for further comparative investigations, by taking into consideration more remote and recent time intervals.

August is characterized by the lowest mean value of the aridity index. This result is common to other studies focusing dryer areas, such as the Romanian extra-Carpathian regions. While the monthly average value for Brasov is 37.5, more than 30% of the extra-Carpathian area is characterized by mean values under 20 [6]. Despite the difference in the averages it is noteworthy that in Brasov, in the twenty years study period, there were six years with aridity indices values lower than 20. In particular years the values could be very low indicating very dry conditions. In the study period, the minimum values for August were 5.5, 7.1 and 8.8. Such values are typical of much more arid regions. For instance, in northern Greece [4] the values of the de Martonne index In August (averages for thirty years) are spanning from 2 to 14, with most of the region characterized by values between 5 and 8.

For analyzing the effects of climate fluctuations on local forests, the water requirements or aridity sensitivity of particular tree species has to be considered. Norway spruce (*Picea abies* L., H. Karts.) is an important tree species in the mountain forests near Brasov and for its growth the weather in June plays a very important role [2]. Thus in the years with a drier June (it resulted that aridity index values under 30 and 20 could occur once every three and five years respectively) the spruce stands are probably affected. Another local tree species, European fir (*Abies alba* Mill.), is very sensitive to water stress and its survival is related to de Martonne index average values over 45 [3]. Over the study period there were very numerous dryer months, when the fir stands were affected and this could be related to the high rate of mortality recently observed.

The data downscaled for Brasov region for the A2 and B2 climate change scenarios [12] show that the average annual rainfall amount would be quite similar (779.9 mm for A2 and 733.2 mm for B2, as compared with 787 mm for 1985-2004) but the monthly values would be considerably different and this induces high differences in the aridity conditions. In March, April, May and September the average values of the aridity index indicate considerable water deficit, June and August resulted to be excessively wet and July similar to the present.

5. Conclusions

Climates are often characterised by using long period averages but an appropriate understanding of the climate conditions requires the analysis of the inter-annual variability, especially in the context of the possible climate changes.

As expected for this region, the average values of the aridity indexes indicate a climate with enough humidity, but by analysing the monthly charts, with the probabilities for different values in individual years, it occurs that dry months are quite frequent. In the study area, one should expect a month with water deficit (an aridity index below 30) once every three years and even very dry or extremely dry months could occur. Very wet or excessively humid months (with aridity indices over 50 respectively 60) have considerable chances to be recorded (with probabilities variable from one month to another, as previously discussed).

Particular monthly values, considerably different from the averages, are not always related to climate change, but induced by regular climate variability. Certainly the effects of extreme weather, very dry or with heavy rainfall, even typical of the normal climate are associated with specific damages, which could induce the subjective perception of an abnormal situation.

The analysis of the monthly aridity variability is very useful in identifying real climate trends. Using the probabilities associated to certain aridity index values one could estimate the risk of damages in a spring forest plantation or the possible requirements of irrigations in a nursery, consequently having a better support in the decision making process.

It is said that climate is what we expect and weather is what we get, however one should not expect the averages but take into consideration the probabilities associated to certain values.

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