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Full Length Research Paper

The pluviometrical deficiencies in the pluvial cereal regions in Algeria

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This study evaluates the ten-day period pluviometry variation in the cereal regions in the north of Algeria, through a period of 73 years (from 1936 to 2009). This variation emphasizes the rainy ten-day period and the dry ones, at the thresholds of rains selected for more than 0, 1, 5, 10, 20 and 30 mm. By extent, the number of the rainy days, their received volumes and their probability to occur are determined. This step relies on the Markov chain of the order 1. The results show a repartition of average pluviometrical quantities, and the number of rainyday per periods of ten days; such a repartition which is irregular and weak in relevance to the increase of the pluviometrical thresholds, on the regional and the national scales. The rain probabilities of occurrence evolve indeed, between 41 and 80%, according to the considered percentages of 20, 30, 50 and 80%. Strong water deficiencies characterize the ten-day periods through the year, which interpret dry sequences in relevance to the resistance of the pluvial cereals to drought of 5, 10, 15 and 20 days. Some droughts of ten days reach 60 to 70%, which suit the soil, the seed and germination preparations, and arrive to 90% during the formation and the maturation of the cereal grains. Water deficiency is noticed, compared with the cereals needs during the yield accomplishment; whatever are the dates of the practiced sowing, from the East to the West of the country.

Key words: Algeria, pluviometry, water deficiency, drought, cereals, sowing.

INTRODUCTION

The extended North of Algeria is an ancient cereal soil, on this space the cereal sum which is yearly sown with wheat or corn verges on 3 million hectares (Mha). The cereal cultivation is exclusively practiced on the pluvial system, in alternation with a lying fallow, within an area equivalent to 3.5 Mha (BSA, 1998 to 2011). Its average production is 25 million quintals, which offers an average yield of the weakest (CNUCED, 2007), in spite of the increasing interest granted to the cereal cultivation by the authorities.. The cereals extended under an annual average pluviometry that varies from 300 to 650 mm, that is an average even rain of 470 mm. Although water strips reflect quantities theoretically sufficient to fill in the cereals needs, their correlation with the cereal production does not explain all the so-called influence of the annual pluviometry (Smadhi and Zella, 2009). Indeed, it is not the annual pluviometrical average that matters much, but above all its space-time repartition. In addition to that, there is the nature of the soil and its topography where the influence is remarkable. Thus, with an equal pluviometry, some parcels can present different cereal yields. Many experiments performed in experimental stations in the Maghreb countries (Assabah, 1994; Zair et al., 1996), could show that the yields in the pluvial system often attain 50 to 60 q/ha. It is a result that other experiments (Benseddik, 2000; Merabet and Bouthiba, 2005) could affect in the irrigated system. In Tunisia, Yadh (2001) showed that in spite of a sufficient annual pluviometry, the rainy day frequency during the vegetative cycle engenders a water deficiency of 100 mm and which ends in 20% drop

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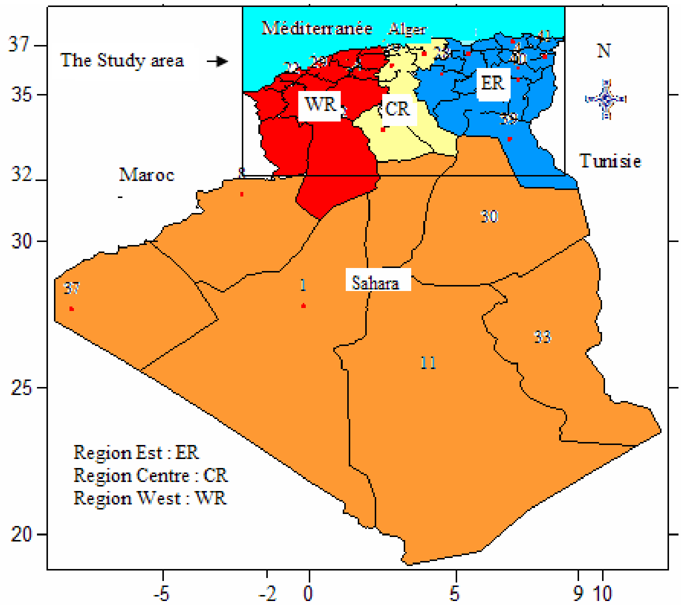

Figure 1. Geographical location of the study area. Scale 1/40, 000000.

of the production. The rainy day notion in the agronomic sense is debatable. Doorembos and Pruitt (1986) define a rainy day by the availability of 60 to 80% of the brute rain. On the other hand, Hills and Morgan (1981) precise that a day is considered rainy if the precipitation water strip is equal or beyond 5 mm. Rain efficiency is therefore linked to minimum and maximum thresholds. Moreover, according to Davey et al. (1976), the deficiency may be as well represented by the pluviometrical duration between the beginning and the end of rains, and by calculating the probabilities of the dry periods or sequences on the annual, monthly or the ten-day periods scales.

The studies related to these subjects, rather on the space than on the time scale, are very rare, even not existing in Algeria. This present study tempts an analysis of the pluviometry of the ten-day periods, according to a progressive space scale (district administratif or wilaya, region, North of Algeria) and a time scale going from 1936 to 2009. These scales contribute to emphasize the agroclimatic water deficiencies, as well as the droughts that probably inhibit the cereal production and productivity (durum wheat, common wheat, barley and oats).

MATERIALS AND METHODS

The study area

The study area covers the three cereal regions in the North of Algeria (NA) which extend on 35.9 Mha that is 17% of the national territory (Figure 1). By considering these regions, the East region (ER), the center region (CR) and the West region (WR), a latitude pluviometrical rule, decreasing from East to West (740,347 mm) is emphasized. Each region occupies respectively 36, 17 and 47% of the total study area. The area of study has 38 wilayas where the weather stations are positioned and giving data rainfall.

Pluviometry

The 76 rain stations belong to the meteorological network of the National Agency of Meteorology (ONM) and the National Agency of the hydraulic resources (ANRH). This number is distributed within 41% in the ER, 22% in the CR and 37% in the WR.

The data of the total rain were extracted by the daily scale (24 h), in a period of 73 years (1936 to 2009). This scale permits to diagnose the rainyday(RD), the dryday(DD), the beginning and the end of the rains and the received quantities from September (S) to June (Ju). The diagnosis which was realized in the case of this study, considered the pace of the periodical ten day time, representing water increase which integrates the time-space distribution on the cereal regions.

Statistical evaluation

Some statistical models which permit to analyze series of pluviometrical data have been published in literature (Herrera et al., 2006; Parent and Bernier, 2007), and the most used among them relies on the Markov chains. This model which is applied in the monthly and the ten-day periods pluviometry in Central Africa (Léonard, 2001 and Van Vyve, 2006), and in West Africa (Sivakumar et al., 1993), has seemingly given quite good results. Talking about the same, in France (Galloy et., al 1982), and in Tunisia (Bergaoui, 1983 and Benzarti et., al 2001), being tested on monthly, seasonal and annual pluviometry, it has given satisfying results. In Algeria (Dechemi et. al 2000), this model has been applied to the coastal rain in order to detect eventual changes in the pluviometrical system. This model based on Markov chain, will be exploited in this study.

The analysis of the periodical ten-day rain series from September to June is therefore bordered by a model with five variables. These variables are studied according to the approach of the Markov chain of order 1. The followed steps are supposed to calculate, per periods of ten day, the dry days' sequences (Sp) and the dryday (DD) evolution, the quantities of the collected rains, the probable water deficiency and the dry days' sequences, knowing that the rainydayare irregularly altered by the dry days. The series of the daily pluviometrical data are thus simulated to a matrix composed of two states: a rainy one, and a dry one. The first represents all the values of rain equal or superior to the pluviometrical thresholds × mm, noted $R_{\geq xmm,}$ it is represented by the number 1. The second represents all the values inferior to these thresholds and it is signaled by the number 0.

The rain series matrixes recently advised, contain values equal only to (1) and (0), remembering that, according to Parent and Bernier (2007), for a Markov chain of order 1, the state of the variable (rain) in the time *(t)*, depends only on its state in the time *(t-1)*. This movement ends at the evaluation of the rain occurrence probabilities and the agroclimatic water deficiencies and/or the ten-day periods dry sequences. These parameters illustrations contribute to simulate the probable dates of the cereals sowing in the pluvial system.

Pluviometrical thresholds

During the period of 1936 to 2009, the selected thresholds are represented by: ($R_{\geq 0,1mm}$), ($R_{\geq 5mm}$), ($R_{\geq 10mm}$), ($R_{\geq 20mm}$) and ($R_{\geq 30mm}$). The first threshold is held to characterize the meteorological ten-

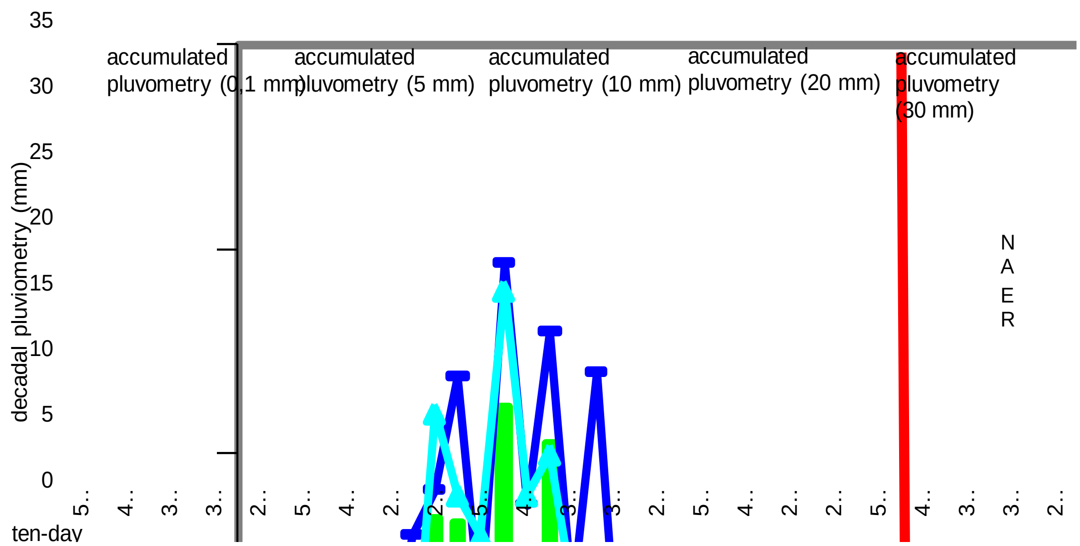

Figure 2. Evolution of the average ten-day rains with thresholds superior to 0, 1, 5, 10, 20, 30 mm in the ER, CR and WR in reference to the average of the study zone.

day rains from September (S) to June (Ju). The second threshold is used to characterize the agricultural ten-day rains. Finally, the three last thresholds inform about the satisfaction of the cereals needs of water, from the sowing until the grains maturation.

During the frequent calculations, the ($R_{\geq 30mm}$) threshold proves a limit in the model, relative to the rarity of rains superior to this threshold, distinguished by a parameter of the (K) form of the pluviometrical series equation, particularly weak even negative(to $R_{\geq 60mm}$). The considered thresholds contribute to differentiate the agricultural and meteorological rains, according to Heathcote (1973) and El hassani (2008).

Laborious calculations, going from simple averages to the resolution of complex equation systems, are facilitated by using Instat Software, version 3.7, which is, according to Sivakumar et., al (1993), well adapted to the climatic events calculation.

Agroclimatic water deficiency

The average agroclimatic water deficiency from S to Ju, on the regional scale, is analyzed by suggesting five hypotheses. The first lies on the best occurrence in each ten-day period of the month, of receiving the first $R_{\geq 0,1mm.}$ The second, third, fourth and fifth hypotheses represent respectively the best occurrences of receiving during all the months' ten-day periods, the first $R_{\geq 5mm}$, $R_{\geq 10mm}$, $R_{\geq 20mm}$ and $R_{\geq 30mm,}$ on the average year. The rains strips occurrences are evaluated to the probabilities of 20, 30, 50 and 80% in relation with the dry sequences definition. These sequences represent the ten-day period where rain quantities inferior to the defined thresholds are received, and are eventually calculated to the probabilities of 20, 30, 50 and 80%, on the time-space scale. These percentages are relevant to the cereal agriculture resistance to a drought duration estimated to 5, 10, 15 and 20 days. They are also relevant to the satisfaction of the ten-day period water needs, the simulation of the sowing dates, as well as the other factors of elaboration of the cereal yield (from germination to the grains maturation).

Sowing date

During the simulation of the cereals sowing dates, a quantity of 40% is removed from the ten-day pluviometrical strip. This combination permits to estimate the water reserve in the first 15 cm of the soil during the 5, 10, 15 and 20 days. The calculations are realized in reference to the sowing dates that were fixed at the start, simulating a precocious, intermediate or late sowing. When a scenario is selected, the model searches the first possible date to manage a sowing (soil moisture superior to 5 mm per ten days). When this requirement is not fulfilled, another sowing date is searched and the sum of rains in the considered ten-day period is superior to 10 mm. In case the test is negative, the sowing test frequency is repeated for sums of 20 then 30 mm.

The estimation of each sowing date generates a set of obtained climatic sequences (rains occurrence) for each cereal year (73 years). The distinction between the obtained dates is checked by the Student test, according to the following hypotheses:

$H_{0:}$ The two dates are identical (they provoke identical climatic events)

$H_{1:}$ The two dates are different (difference of the events); with a degree of freedom or 'degré de liberté' (DDL) = N1+ N2- 2 and (N1: the size of the first group of dates

N2: the size of the second group of dates

T_{critic}= 1.73 on the level of signification P<0.05).

This step permits to simulate sowing dates in some cereal wilayas (Setif in the ER, Bouira in the CR and Tiaret in the WR).

RESULTS

Pluviometrical quantity

The average repartition to the thresholds of $R_{\geq 0,1\ mm}$, $R_{\geq 5\ mm}$, $R_{\geq 10\ mm}$, $R_{\geq 20\ mm}$ and $R_{\geq 30\ mm}$ differs by the rain settlement and the average pluviometrical gathering received per ten days from S to Ju, along the period of 73 years. Figure 2 reflects these characteristics in reference to the average of all the extent of this study.

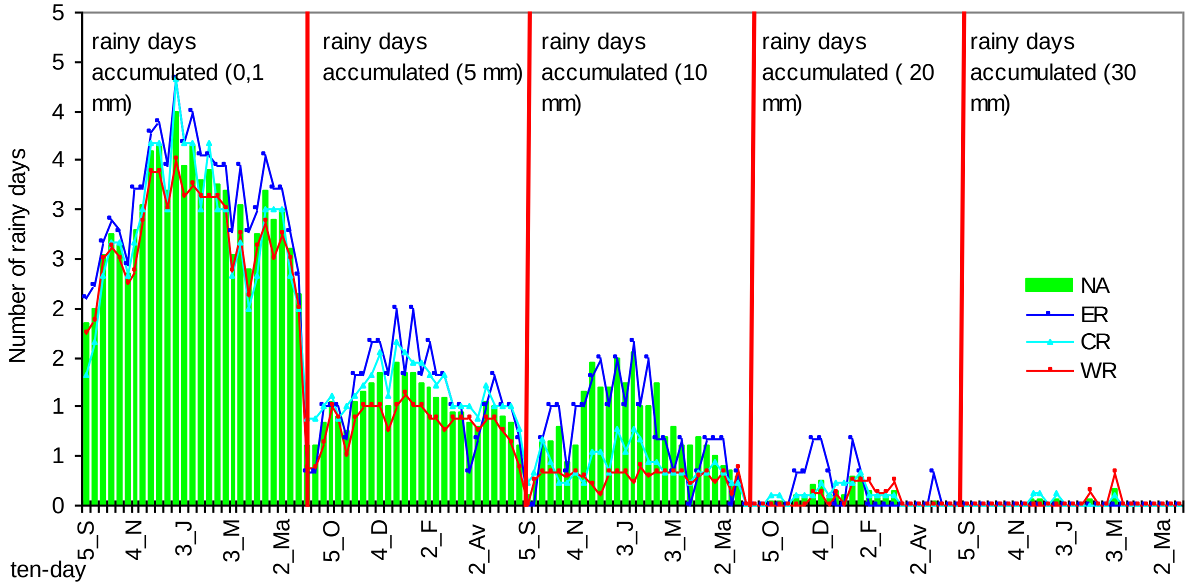

Figure 3. Evolution of the rainydaynumber at the rains thresholds superior to 0, 1, 5, 10, 20 and 30 mm in the ER, CR and the WR in reference to the NA.

Threshold of $R_{\geq 0,1\ mm}$

At this threshold, the rains appear since the first ten day of the month that is from 5th to 15th September to in the three regions. The averages of 13 (ER), 7 (CR) and 6 (WR) mm, fluctuate around the national average (9 mm). Regionally, these quantities of rain increase regularly, to attain the maximum values on the 8th of the ten day (from 14 to 24 November : N). The most watered ten-day periods of the cereal year are those of December (9th, 10th, 11th D) and of January (12th, 13th, 14th J). Their water strip comprised between 17 and 30 mm, diminish since the 15th ten-day period of February (F), recording the weakest values at the 19th ten-day period of March (M). The rains which restart again at the last ten-day period of the same month, reach their peak at the 24th ten-day period of April (01A-10A), then they diminish as they go along, until the 27th ten-day period of May (Ma), marking the end of the ten-day rains. These rains are respectively 16 mm in the ER, 12 mm in the CR and 10 mm in the WR, with a general average of 13 mm.

The pluviometrical ten day periods of the ER keep the most watered than those of the CR, followed by those of the WR.

Threshold of $R_{\geq 5\ mm}$

The evolution of the ten-day periods of $R_{\geq 5mm}$ follows that one of $R_{\geq 0,1mm}$. However, the date of the rain settlement is delayed to the 2nd ten-day of September in the ER and the CR, and to the 3rd ten-day of September-October (O) in the WR. The average ten-day rains equal to 5 mm, characterize the thresholds limits to be significant. The most watered ten day of the fall season, are therefore the ten-day period of November. Their water strips evolve between 10 and 13 mm, which mean twice the significant rains. Once again, the ten-day periods (10, 11, 12) of D, and the ten-day periods (13, 14, 15) of J are the most watered, with average quantities of 20 mm. They suddenly diminish during the 16th tenday(23J-02F) and during the 19th, 20th and 21th tendayof M. Then, they increase slightly during the three ten-day periods of A. Finally, the 27th tenday(22-31 Ma), with a maximum average of 8 mm, signals the end of the significant ten-day periods of rains from the ER to the WR.

Thresholds of $R_{\geq 10\ mm}$, $R_{\geq 20\ mm}$ and $R_{\geq 30\ mm}$

At these thresholds, according to the curves in Figure 2, the beginning of the ten-day rain is getting later in relevance to the increase of the pluviometrical threshold. At the threshold of $\mathbf{R_{\geq 0,1\ mm}}$, the date of the ten-day rain settlement starts at the 9th tenday(24N to 04D) in the ER. It starts at the 10th (04 to 14D) in the CR. In the WR, whatever is the pluviometrical threshold, the ten-day rains from S to Ma are inferior to those of the average (NA).

Number of the rainy days

In the ER, CR and WR, the average number of the rainy day in the ten-day periods on 73 years, evolves according to Figure 3 in the direction of the pluviometrical volumes at the respective thresholds of 0, 1, 5, 10, 20

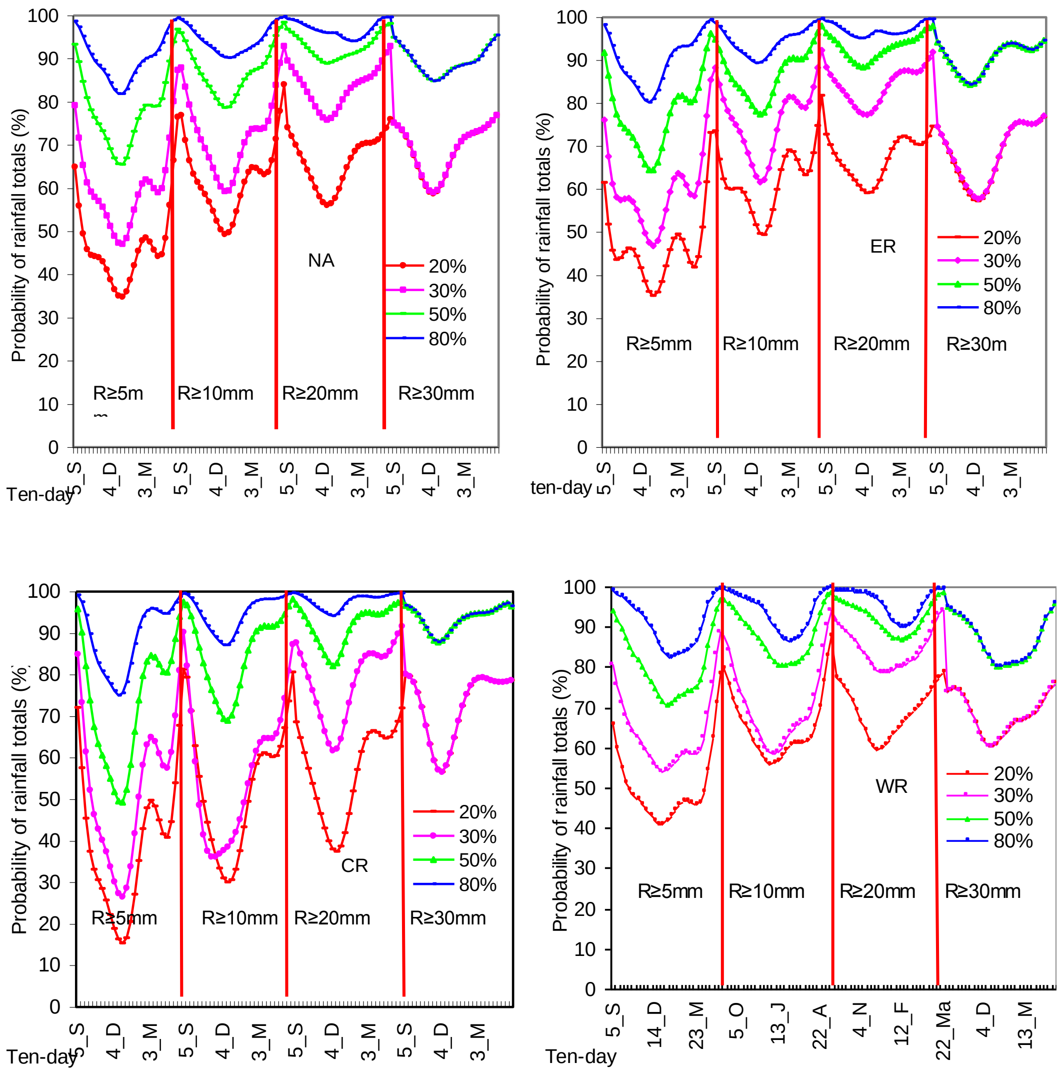

Figure 4. Probabilities of occurrence of the ten-day rains superior to 5, 10, 20 and 30 mm in the ER, CR and the WR compared to the average (NA).

and 30 mm. At the first threshold, the ten-day periods of S, O and N which are relatively more watered comparing with those of M, A and Ma, record however the same number of rainy day per ten days. This number which does not go beyond 2 or 3dayper ten day reaches 4dayonly during the ten-day periods of winter. At the second threshold each of these periods of ten day transcribe 2 rainy days at most. At the last three thresholds, the number of the rainy day per ten day becomes negligible in the three regions. The dry day is therefore dominant along the ten-day periods of the years. The quantities of the average rains and the number of the average rainy day received per ten day on the NA, do not seem in harmony with the repartition of the pluvial cereals needs of water, from the fall phase to the spring phase. This law report can be confirmed by the results of calculations of the probabilities of rains occurrences.

DISCUSSION

The rains occurrences

Regionally, the average probabilities of the significant ten-day rains at the percentages of 20, 30, 50 and 80% are recapped by the curve of Figure 4.

Effectively, the appearance of the obtained curves at 20%, shows that the probabilities of receiving of $R_{\geq 5mm}$ during the ten-day periods which correspond to the soil preparation (September), are comprised between +65 and +49%. These probabilities fluctuate between +46 and +44% during the ten-day periods when the sowing happens (October). They do not exceed +44 and +41% at the ten-day periods which coincide germination (November), while they brush averagely against +49 to 76% when the formation and the maturation of the cereal grains happen. At percentages superior to 30%, the rains

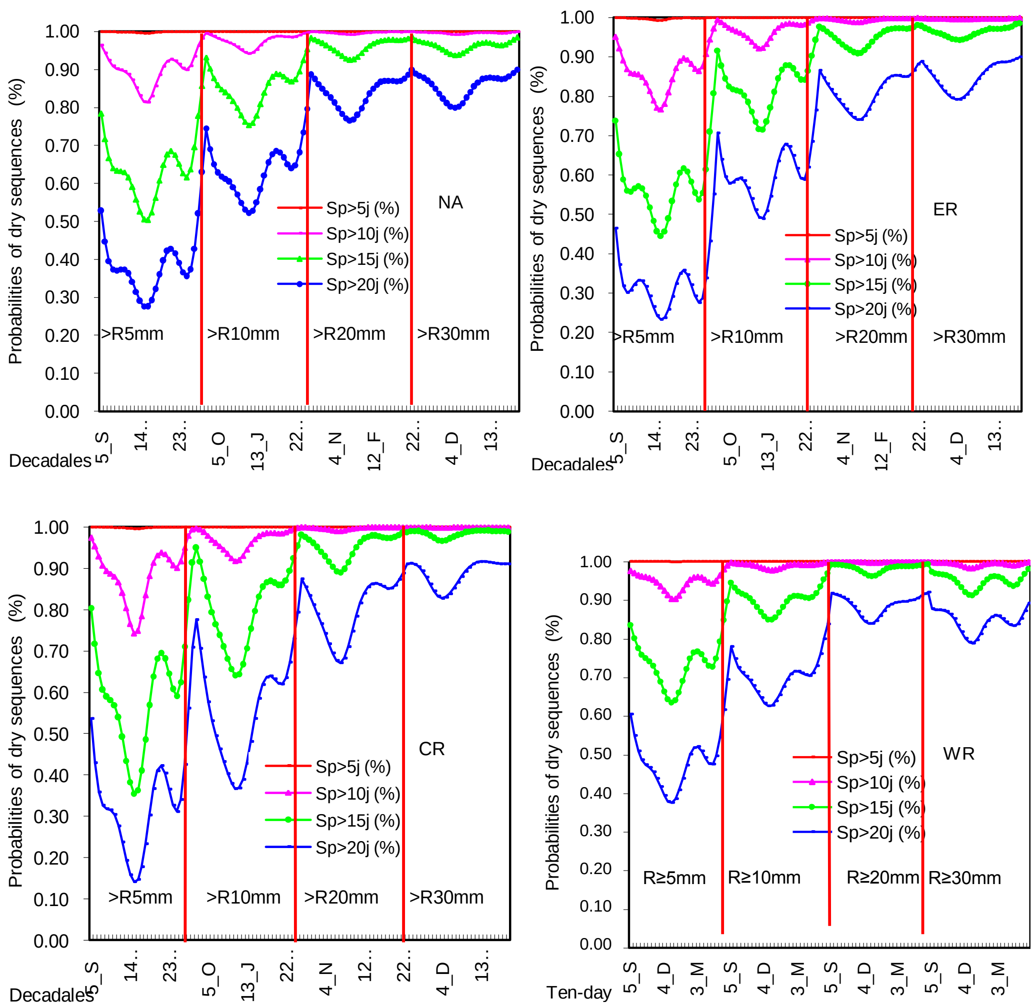

Figure 5. Probabilities of dry sequences superior to 5, 10, 20 and 30 mm in the ER, CR, WR and in the NA.

probability is increasingly significant, by attaining 80%, and the maximum (86%) in the spring ten-day periods.

At the thresholds of $R_{\geq 10\ mm}$, $R_{\geq 20\ mm}$ and $R_{\geq 30\ mm}$

The curves of the same figure show that the ten-day rains probabilities of occurrence develop more and more. This development hides the distribution of the ten-day rains obtained in majority at the percentage of 80%, in the three regions. These results make us notice a bad repartition of the significant rains during all the ten-day periods from S to Ma. Strong water deficiencies seem to characterize the sowing, germination, fructification and the maturation of the pluvial cereals in the NA.

The occurrence of the agroclimatic water deficiency

Regionally and territorially, the agroclimatic water deficiency which illustrate the ten-day periods from S to Ju, are explained by Figure 5. This figure shows that whatever is the pluviometrical threshold, until the beginning of the ten-day periods of D, the probabilities of droughts over 5, 10, 15 to 20dayalong the 30dayof the month, increase to more 60%. These results certify that some sowing practiced during these ten-day periods, are very critical. The following ten-day periods (of D, J and F) unfortunately seem so unfavorable, even if the probabilities of dry sequences diminish. Since the ten-day periods of M, the probabilities of the maximal droughts which exceed 10daygrow to 92%. These results corroborate those previously obtained, confirming a water shortcoming in relevance with the phases of the yield elaboration in the ER, CR and the WR.

Overall, the ten day rainfall variability characteristics of NA, complements the work of Seltzer (1949) for the period (1913 to 1939), Chaumont and Paquin (1972) for the period (1952 to 1970) and Meddi and Meddi (2009) period (1930 to 2003). Variability described is causing

Table 1. Sowing dates of the pluvial cereals at thresholds suggested by the pluviometrical model in reference with the fixed dates at the entrance.

Region	Wilayas	D.S.R	5 O	15 O	25 O	4 N	14 N	24 N	4 D	14 D	24 D
	Sétif	Mx	12^{J}	12^{J}	12^{J}	12^{J}	12^{J}	12^{J}	12^{J}	12^{J}	12^{J}
ER	Setif	M	03^{N}	03^{N}	03^{N}	05^{N}	06^{N}	06^{N}	06^{N}	06^{N}	06^{N}
	Setif	SD	06^{N}	06^{N}	06^{N}	06^{N}	4^{D}	4^{D}	4^{D}	4^{D}	4^{D}
	Bouira	Mx	24^{A}	24^{A}	24^{A}	24^{A}	24^{A}	24^{A}	24^{A}	24^{A}	24^{A}
CR	Bouira	M	30^{D}	24^{D}	30^{D}	31^{D}	01^{J}	04^{J}	25^{J}	27^{J}	29^{J}
	Bouira	SD	06^{N}	12^{N}	06^{N}	06^{N}	02^{N}	26^{O}	23^{O}	29^{O}	29^{O}
	Tiaret	Mx	31^{J}	31^{J}	31^{J}	31^{J}	31^{J}	31^{J}	20^{M}	20^{M}	20^{M}
WR	Tiaret	M	13^{N}	25^{N}	26^{N}	27^{N}	2^{D}	20^{N}	25^{D}	25^{D}	09^{J}
	Tiaret	SD	03^{O}	28^{S}	27^{S}	25^{S}	23^{S}	11^{O}	03^{O}	14^{O}	16^{O}

D.E.R, Sowing dates of reference; Mx, maximum date; M, average date; SD, deviation standard.

annual and seasonal droughts climate. It also converges in the sense of droughts that hit neighbouring regions of Morocco (Zeggaf et al., 2002) and Tunisia (Bergaoui and Alouini, 2001).

The sowing date

In relation with the results of the ten-day pluviometry (water deficiency, droughts), dates of eventual sowing of the pluvial cereals in the cereal wilayas of the ER, CR and the WR are synthesized in the Table 1. These dates reflect a precocious, intermediate and late sowing. The application of the Student test to the sowing dates suggested by the used model, at a significant threshold of $P<0.05$, confirms that there is no difference between the dates presented by the model in reference to the entrance dates. In other words, whatever is the considered sowing date, no particular pluviometrical event (rains occurrence), acts indistinctly on the period of the cereal flourishing.

Conclusion

The examination of the ten-day periods rains shows that whatever is the considered pluviometrical threshold, a water deficiency is apparent along the cereal year. This deficiency is represented by the decrease of the quantities of the significant rains superior to 5 mm by the reduction of the number of the ten- day periods rainy days. Its probability of occurrence which fluctuate between +49 and +80%, from autumn to spring, determines in time and space hard climatic and agricultural droughts. These droughts disturb the full due of sowing, germination and all the cereal cycle. An adaptation of the pluvial cereal agriculture to the droughts impact and eventually to the climatic changes proves very crucial for a durable development and a food security of the country.

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