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Article

Assessing the Dynamics of Major Cereals Productivity in Algeria: Case of Setif

Limani Yacine [1,*], Madani Toufik [1] and Khaznadar Mouna [2]

[1] Department of Agriculture Sciences, Laboratory for Valorization of Natural Biological Resources, Faculty of Natural and Life Sciences, Setif 1 University Ferhat Abbas, Algeria.
[2] Laboratory for Valorization of Natural Biological Resources, Faculty of Natural and Life Sciences, Setif 1 University Ferhat Abbas, Algeria.
* Correspondence: limaniyacine@gmail.com

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Abstract: In this study, five methods were used to find instability and the growth trend in yield for four cereal crops (Durum wheat, Bread Wheat, Barley, and Oats) in Setif -Algeria-. The data source used to evaluate the growth trends and instability in yield is the mean grain yield of ten years (2014-2024). The graphical analysis demonstrates that the growth trends in Bread wheat its positive; but the DCI -Cuddy Della Valle Index- classified it as a high-instability crop. In addition, the combined analysis of both instability indices (Coefficient of Variation (CV) and Coppock Instability Index (CII)) proved that both species of Barley and Oats are very unstable crops. The scarcity of data related to the crop unfortunately did not allow us to make a real assessment of the trend of growth and instability in the yield of the main crops used in Setif -Algeria.

Keywords: *Algeria; dynamics; cereal; growth trends; instability index; coppock instability index.*

1. Introduction

Around the world, cereals have been considered the principal component of the human diet among food crops, for thousands of years. They constitute rice, wheat, maize, and to a lesser extent jowar and millet. More than 50% of the world's daily caloric intake is derived from cereal grain consumption directly. Today cereal grains are the single most important source of calories in the world to a majority of the population. The agricultural sector is one of the most important sectors in the economy of any country. Its main task is to provide the food needs of the population and thus to achieve food security. Algeria has been unable to guarantee its food security. Algeria is considered to be one of the most food-importing and agricultural countries in the world [1]. In addition, The Algerian territory includes two types of regions: a dominant Saharan zone (84% of the territory) and a coastal zone (16%). The area of agricultural land covers 20% of the total area of the country, about 40 Mha, of which about 8.5 Mha of cultivated area and 31.5 Mha course, to which 4 Mha of forest and maquis. The irrigated area represents 13% of cultivated areas (1.1 Mha). Lack of infrastructure and regular droughts still make the country highly dependent on imports to meet its needs [1]. At the national level, Setif ranked second just behind the wilaya of Tiaret with a cereal production of around 3.6954 million quintals (q), carried out on an area of more than 197,100 hectares (ha) [2]. To quantify the growth rate of cereals production in Setif over the years, this study employs the Compound Annual Growth Rate (CAGR). By utilizing CAGR it was aimed to provide a quantitative understanding of the expansion of cereals grain yield during the study period. In addition, employing analytical tools such as Coefficient of Variation (CV), Coppock's instability index, and Cuddy Della Valle instability index, we endeavor to unravel the volatility and fluctuations in cereal grain yield. Such analysis on the cereal production trends and dynamics in terms of production and

productivity might be useful to understand the cause and effects [3]. Therefore, the present work focuses on the dynamics of major cereal crops over some time and such knowledge might be useful in the implementation of the Agriculture Development Strategy and formulating policies for enhancing the food security situation.

2. Materials and Methods

2.1. Description of the study area

The province of Setif which covers 6.549 km² (0.27% of the national territory) is situated in the Eastern part of Algeria, between 35.0° and 36.5° of latitude North and 5° and 6° of longitude East (Figure 1). The administrative divisions of Setif Wilaya are composed of twenty districts (Daîras) which are further subdivided into sixty municipalities [4]. Therefore, it has a continental semi-arid climate with cold and wet winters and dry and hot summers. The province is traditionally subdivided into three agroecological zones. The North has black and deep vertical soils, with a clay-to-clay-loamy texture and an annual rainfall of 600 mm [5]. This agro-ecological zone was represented by the northern study zone; characterized by a mountainous topology and rugged lands. However, the central zone, or plains zone; is characterized by wide plains suitable for agro-pastoral activities. The southern zone included the mountain chain of Boutaleb, culminating at 1886 m ASL, where the annual rainfall does not exceed 300 mm and soils are brown calcareous [6]. The agricultural statistics registered in 2024 at Setif state, show that the grain yield of the major cereals is Durum wheat: 11.45 (Qx/ha), Bread wheat 14.39 (Qx/ha), Barley: 10.33 (Qx/ha), Oat: 11.86 (Qx/ha). In addition, the grain yield of horticultural crops including potatoes is 314.74 (Qx/ha), and legumes are 317.38 (Qx/ha) [7]. The insufficiency, irregularity of rainfall, and seasonal hot winds (sirocco) occurring during the end of the vegetative cycle, drastically affect the cereals crops [8].

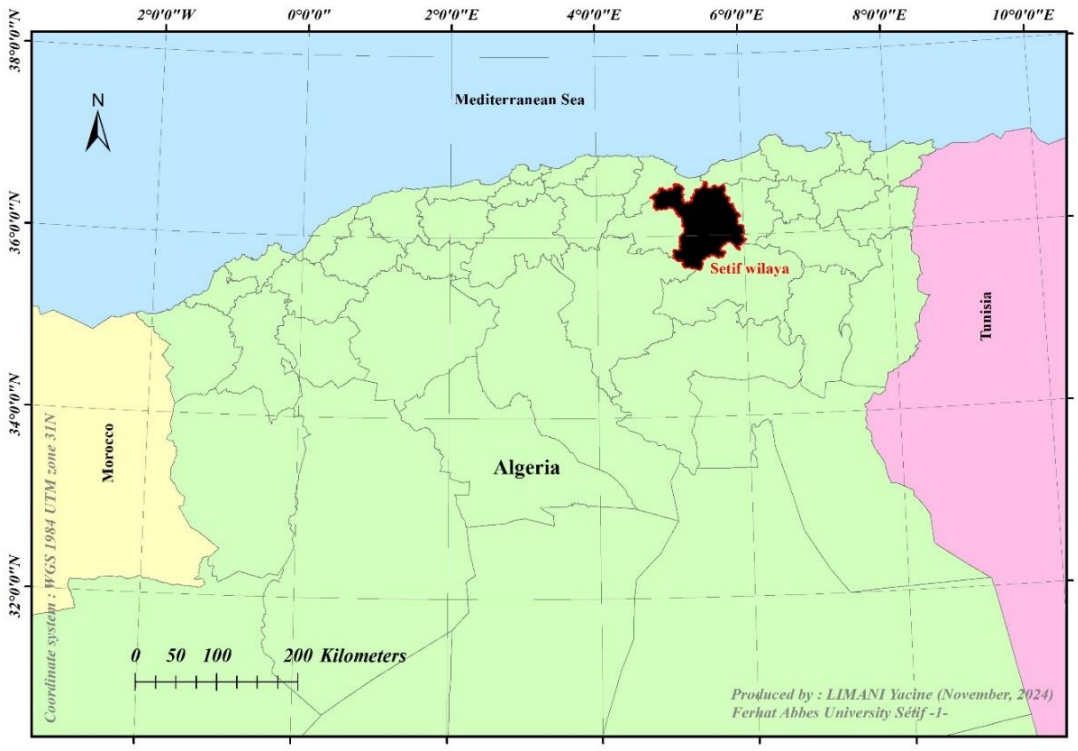

Figure 1. Location map of the study area.

2.2. Source of data

The source of the data used to carry out this study is the management of the budget programming and monitoring department of Setif (Ex. planning and land use planning department commonly called: DPAT). The data we acquired concerns agricultural production in general and plant production of

cereals in particular, for the time series: 2014 to 2024. These statistics relate to durum wheat, soft wheat, barley, and oats in terms of sowing area (in hectares), harvested area (in hectares), and production (in quintals). From this, we deduced the yield or productivity expressed in quintals/hectare.

2.3. Growth and instability indices

2.3.1. Growth indices

2.3.1.1. Compound annual growth rate (CAGR)

Growth rates are worked out to examine the tendency of variables to increase, decrease, or remain stagnant over some time. It also indicates the magnitude of the rate of change in the variable under consideration per unit of time [9]. For the present study, the Compound Annual growth trend was used to estimate the growth of the productivity of cereals in Setif. The high values of this index mean good growth. The Compound Annual growth rates were computed by using the function of the form:

$$CAGR = [(Ending\ Value/\ Beginning\ Value)^{1/n}-1] \quad (1)$$

2.3.1.2. Annual growth rate (AGR)

Growth rates refer to the percentage change of a specific variable within a specific time. Growth rates can be positive or negative, depending on whether the size of the variable is increasing or decreasing over time, the high values of this index mean good growth. The mathematical representation of the Annual Growth Rate over a specific period is derived from the following formula [10]:

$$AGR = [(End\ value - First\ Value)/\ First\ Value]x100 \quad (2)$$

2.3.2. Instability indices

2.3.2.1. Coefficient of variation (CV)

The coefficient of variation (CV) is a relative variability measure, expressing the dispersion of data values around the mean, to find out the variation in any time series data, a simple analytical technique like coefficient of variation is useful [11]. A low value of this index indicates low instability in agricultural production and vice-versa. It is estimated as follows:

$$CV = (SD/\ Mean) \times 100 \quad (3)$$

Where:
SD = Standard Deviation

2.3.2.2. Cuddy della valle index (CDI)

The Cuddy-Della Valle index, introduced by [12], aims to eliminate the influence of trends in the coefficient of variation (CV) by utilizing the coefficient of determination. Data on crop area and productivity were determined using linear relationships. Many researchers, [13-14] have applied the CDI method to measure variability in time-series data, considering it a superior approach for capturing instability in agricultural production. It is estimated as follows:

$$CDI = CV\sqrt{(1 - R^2)} \quad (4)$$

Where:
CV: Coefficient of Variation in percent
R^2: Adjusted Coefficient of Determination

The levels of instability are categorized within the following ranges:
Low instability: 0-15
Median instability: 15-30
High instability: >30

2.3.2.3. Coppock instability index (CII)

Coppock's instability index serves as a relatively accurate estimation of the annual percentage variation, accounting for the underlying trend. Its primary advantage lies in its ability to gauge the instability within price trends. A higher numerical value on the index signifies a more significant degree of instability [15].

$$\text{CII} = (\text{Antilog}) \sqrt{(V \log -1)} * 100 \quad (5)$$

$$\text{V log} = 1/(N-1) \sum(\log p_{t+1} - \log p_t - M)^2 \quad (6)$$

$$\text{M} = 1/(N-1) \sum(logp_{t+1} - \log p_t) \quad (7)$$

3. Results and Discussion

3.1. Grain yield growth trends of cereal crops

Trend analysis in the grain yield of Durum wheat, Bread wheat, Barley, and Oats for a period of ten years in Setif was studied using Compound Annual Growth Rate (CAGR) and Annual Growth Rate (AGR). As shown in Figure 2, the productivity of Bread wheat is increasing in contrary to Durum wheat, Barley and Oats were decreasing. For the Bread wheat, the grain yield increased from 7.37 Q/ha in 2014 to 14.39 Q/ha in 2024, respectively.

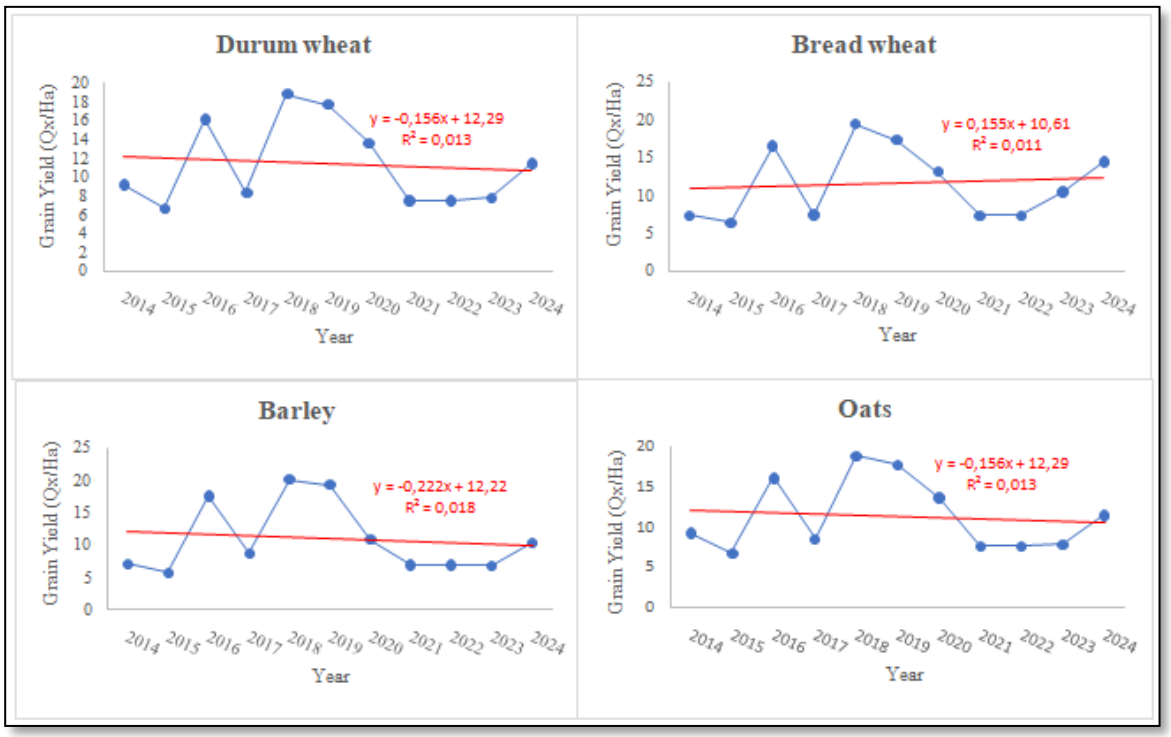

Figure 2. Growth trends of Durum wheat, Bread wheat, Barley, and Oats in Grain yield during the test period in Setif.

Compound Annual Growth Rate of major cereals is shown in Table 1. In Bread wheat and Oats, the mean values of CAGR increased significantly and the ANOVA analysis provided that there is no significant difference between the cereals type mentioned above.

In addition, Durum wheat and barley registered negative values for CAGR which indicate decreases in grain yield growth over the testing period.

Table 1. Compound Annual Growth Rate and Annual Growth Rate of the tested cereals in Setif.

Growth index (%)	Durum wheat	Bread wheat	Barley	Oats	LSD 5%
CAGR	-5.62±29.59 (b)	9.37±6.05 (a)	-5.43±32.97 (b)	4.40±22.12 (a)	16.21
AGR	30.53±25.38 (b)	38.83±17.61 (ab)	52.65±69.64 (a)	45.55±36.80 (ab)	27.29

CAGR: Compound Annual Growth Rate, AGR: Annual Growth Rate, LSD5%: Least significant differences at 5%. In each line, values with different letters indicate significant differences at 5%.

Many studies on the growth and the instability of the grain yield of Bread wheat are following our results which indicate a significant increase over time [16]. The mean value of CAGR in barley is (-5.43 %), among the results that agree with what we get from the results of [17] which indicate a negative value of CAGR for the Barley (-1.13 %) production during a large period from 1952 to 2021 in India. Based on the values of the Annual Growth Rate (AGR) the best growth in grain yield is registered by Barley (52.65 %) and Oats (45.55 %), with no significant difference at 5%. These results provide the large adaptability of both cereal types under different climatic conditions. In addition, [18] reported that after the green revolution period in India, positive production growth was found in barley. As shown in Figure 2 and Table 1 both cereals Barley and Oats registered increasing growth rates but still, like this negative production growth trends are reported in many states in India [18].

3.2. Instability in grain yield of cereal crops

Instability was analyzed using the Coefficient of Variation (CV), Cuddy Della Valle Index (CDI), and Coppock Instability Index (CII) presented in Table 2.

3.2.1. Coefficient of variation (CV)

According to the coefficient of variation (CV%), the ANOVA analysis divided the four cereals tested into two groups; the first one with the highest values of CV registered by Barley and Oats, 71.09% and 64.86%, respectively, and the second group with moderate values are showed by Durum Wheat and Bread Wheat (Table 2).

Table 2. Instability indices of Grain yield for cereal crops tested in Setif.

Cereal Type	CV (%)	CDI (%)	CII (%)	Mean of GY (2014-2024)
Durum wheat	54.01±25.10 (b)	28.92±27.69 (a)	64.75±11.30 (b)	11.40±2.35 (a)
Bread wheat	57.09±11.84 (b)	40.14±14.91 (a)	67.09±9.29 (b)	11.84±3.67 (a)
Barley	71.09±32.57 (a)	35.03±35.03 (a)	73.74±16.21 (a)	10.98±2.63 (a)
Oats	64.86±11.42 (ab)	37.65±18.24 (a)	70.31±10.78 (ab)	10.57±2.73 (a)
Mean	61.76	35.43	68.97	11.2
Min	54.01	28.92	64.75	10.57
Max	71.09	40.14	73.74	11.84
LSD 5%	14.70	16.34	7.54	1.33

CV: Coefficient of Variation, CII: Coppock Instability Index, and CDI: Cuddy Della Valle Index. LSD5%: Least significant differences at 5%. In each column, values with different letters indicate significant differences at 5%.

The coefficient of variation assesses the relative dispersion of data around the mean. A higher CV indicates greater variability. Many studies registered small values in CV% variation for Barley crop, 16.64% during (1989-2017) in India [18] and 19.6% during (1950-2021) in Pakistan [19], which indicates that the barley grain yield variation in Setif during the tested time it's very big which affects negatively the growth of grain yield.

3.2.2. Cuddy della valle index (CDI)

The Cuddy Della Valle Index (CDI) is a measure of instability in a time series data set. As shown in Table 2, the ANOVA analysis reported that there is no significant difference between the cereal crops tested. Based on the CDI categorization, the variation in the grain yield during

the time of durum wheat is classified as median instability with a value of 28.92%, our finding follows the results of [19] which register medium values in CDI for the wheat crop during the large period (1950-2021) in Pakistan. In addition, the rest of the cereal crops (Bread Wheat, Barley, and Oats) were classified as high-instability crops (Table 2), contrary to the finding of [17] which noted that the variation in productivity based on the calculation of CDI classified Barley crop as low instability crop (CDI: 0-15 %) during the large period time (1952-2021) in India.

3.2.3. Coppock instability index (CII)

The Coppock Instability Index (CII) is a measure of instability in a time series data set, calculated based on the rate of change of the data. A higher CII value indicates greater instability. In our study, the ANOVA analysis divided the four cereals tested into two groups; Durum Wheat and Bread Wheat (Table 2) showing the first group with moderate values, this value of CII is confined between 65-67%. [20] registered a value of CII confined between 38-47%, during the large period (1951-2020) in Pakistan for the wheat crops. In the second group, Barley and Oats registered the highest values of CII, 73.74% and 70.31%, respectively; these highest values indicate large variability in grain yield across the years which means big instability. On the contrary, [17] showed small values of CII for Barley crops that did not exceed 60%.

3.3. The Dynamic of grain yield for the tested cereal crops

Based on the results illustrated in Figure 3A, the mean grain yield of Durum Wheat from 2014 to 2024 divided the Setif state into two regions, the first one (mid to north zone) which content 32 townships with mean grain yield ranging from 11.5 Qx/ha to bigger than 14 Qx/ha. This region is classified as a potential zone for the production of Durum wheat, our results are confirmed by the finding of [21-8]. Exception of five townships (Guenzet, Serdj El Ghoul, Babor, Djemila, and Bousselam), which requires studying the reason for the decline in Durum wheat production, despite its location in a very suitable area characterized by very significant amounts of precipitation and very fertile soils. The second region (mid to south zone) is characterized by two sub-regions. The first subregion (Red color in Figure 3A), forms a complete strip extending from the west of the state to its east, with an average grain yield that did not exceed 9 Qx/ha. The rest of the township constitutes the second subregion with mean grain yield ranging between 9-11.5 Qx/ha (Orange color in Figure 3A). In addition, this region is characterized by scarcity and high fluctuation in precipitation with strong sirocco winds during the grain filling stage, [22] which affect negatively the final grain yield. In addition, the distribution of grain yield for Bread wheat as shown in Figure 3B, data proved that just seven townships registered moderate grain yield ranging from 14.01 Qx/ha to bigger than 19 Qx/ha. About 20 townships of the Setif state showed mean grain yield values between 9-14 Qx/ha. Comparing these results with the results obtained regarding the distribution of durum wheat cultivation in the state of Setif, we note an almost complete match in the areas designated for the cultivation of both Bread and Durum wheat. In addition, the data of grain yield variation in Barley (Figure 3C) proved that his distribution of the cultivation is exactly similar to the distribution of Durum wheat and about 24 townships of the Setif state showed mean grain yield values between 11-14 Qx/ha. In Setif state, the number of townships (34 townships) that cultivate the Oats crop is very acceptable (> 56 % of the total township). As shown in Figure 3D, the biggest value in grain yield is registered just by four townships (Tachouda, El Ouricia, Ain Abessa, and Hamma); its mean grain yield ranged from 14 Qx/ha to bigger than 19 Qx/ha. About 43 % of the state's townships do not cultivate Oats (Black color, Figure 3D). Oats are also grown in some townships with significant rainfall and very fertile soils.

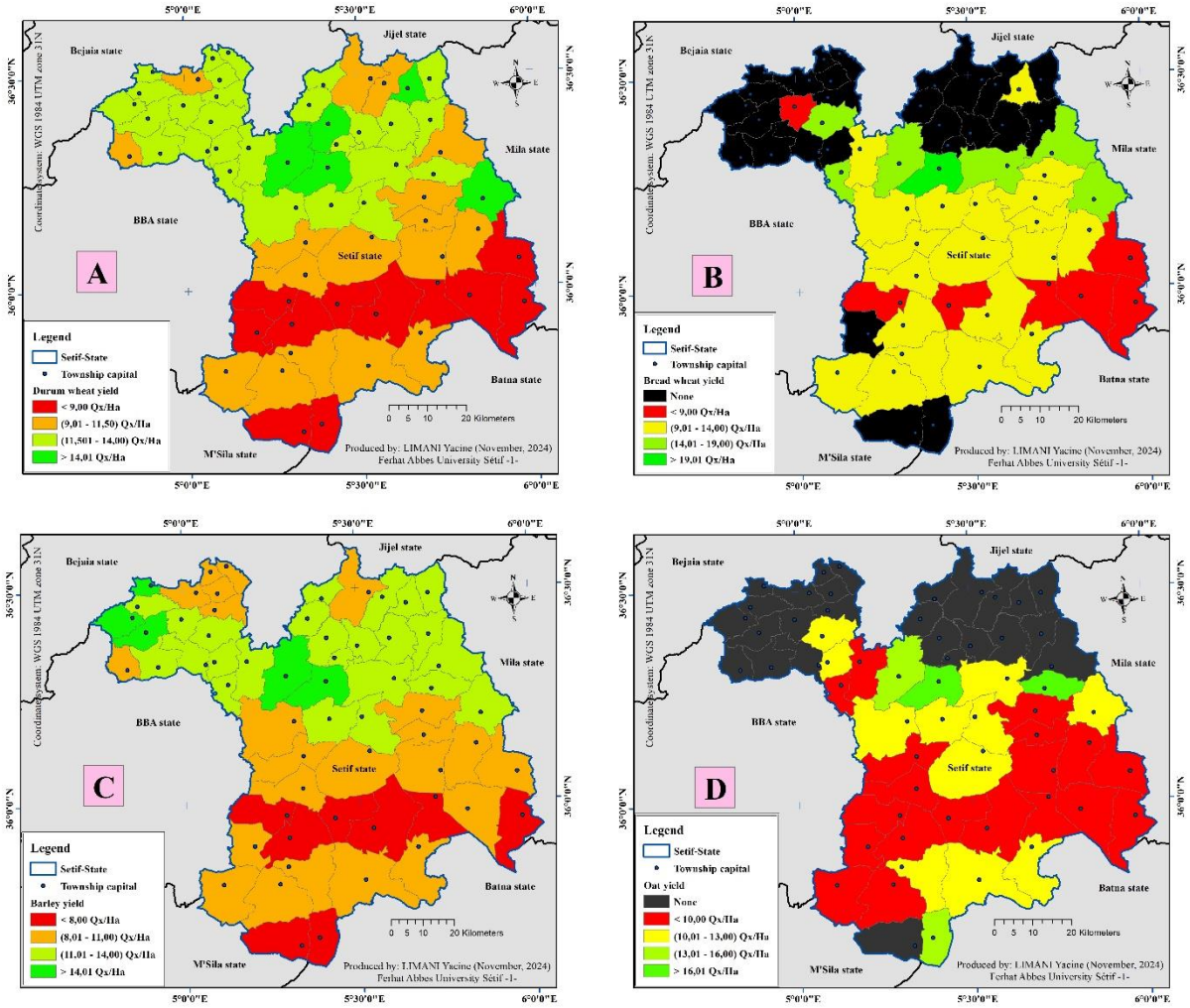

Figure 3. Spatiotemporal variation of mean grain yield for Durum wheat (A), Bread Wheat (B), Barley (C), and Oats (D) during the tested period (2014-2024) in Setif - Algeria.

4. Conclusions

The analytical tools used to evaluate the growth in yield during 2014-2024 are Compound Annual Growth Rate (CAGR) and Annual Growth Rate (AGR). The growth trends during the time tested are positive for Bread wheat, but negative for the rest of the plant species tested. The CAGR method proved a very small growth rate in grain yield for Bread wheat and Oats. Based on the AGR index both species Barley and Oats have the best growth rate in the grain yield during ten years successively. The mixed ANOVA analysis based on the values of CV and CII divided the tested cereals crops into two groups, the first one includes Barley and Oats with the highest values, which indicate high instability. In addition, depending on the CDI category, the variation in the grain yield of Durum wheat during the time classified it as median instability, but the. The rest of the cereal's crops: Bread Wheat, Barley, and Oats classified as high instability crops. The graphical spatiotemporal variation of mean grain yield divided the Setif state into two regions, the first one with favorable conditions of cereal production (mid to north) and the second region characterized by unfavorable conditions, which gives information about the new proposed strategies for this region. Overall, the results of our study proved that the biggest variability from year to year in grain yield for the major cereals used in Setif classified these cereals as moderate to high instability and had negative growth trends.

Conflicts of Interest: The authors declare no conflict of interest.

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