# ORGANIC CEREAL CROPS IN THE WORLD, IN EUROPE AND IN ROMANIA – COMPARATIVE ANALYSIS

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***Abstract:*** *Organic crops have recorded variable dynamics in cultivated areas, with an increasing trend globally. This study analyzed the situation of the area (A) of cereal crops in the organic system worldwide - A(W), in Europe - A(E), and Romania - A(RO), during the 2013 – 2023 period. A trend of increasing area was observed at global level, during the studied period, with an exception in 2014. At the European level, an increasing trend in area was observed during the period 2013-2020, followed by a decreasing trend after the maximum in 2020. At the Romanian level, a downward trend was observed in the first part of the interval (2016 with the minimum value) and an upward trend between 2016 and 2023. Mathematical models of polynomial form described the variation of cereal crop areas in the organic system in relation to the time factor (T, years), with $R^2 = 0.983$ for A(W), $R^2 = 0.980$ in the case of A(E) and $R^2 = 0.946$ in the case of A(RO). According to PCA, the principal components explained 98.564% of the total variance, and Cluster Analysis grouped the years of the study period based on similarity.*

***Key words****: cereals, dynamics, multivariate analysis, organic crops, variation models*

## INTRODUCTION

Cereals (Poaceae: Gramineae) include a series of crop plants (e.g. wheat, rice, barley, rye, corn, millet, sorghum) from which the main production (starch-rich seeds) but also the secondary production (ligno-cellulosic stems) are used in food, animal feed, and as raw material for various industrial sectors [8,20,23,29].

Cereal seeds have a complex content of nutritional principles, such as starch (in the highest proportion), proteins, vitamins, mineral salts, etc., and represent a basic part of people's diets [8,15, 18,19].

Cereal crops and cereal production are analyzed worldwide, and there are studies that predict accelerated growth in cereal production for the horizon 2050 - 2100 in order to ensure food requirements for the human population [25,28].

The area cultivated with cereals and cereal productivity are dynamic, and have been studied in relation to production systems, agricultural technologies, climate change and various limiting factors [7,14,17].

Cereals are grown both in conventional systems and in ecological systems (organic, biodynamic), as a result of the interest in healthy foods, but also for environmental reasons [2,4].

Cereal cultivation in an organic system was analyzed in comparison with conventional systems, from the perspective of the sustainability of crop systems, production quality, the relationship of plants with soil and nutritional factors, climatic conditions, plant protection [3,16,24]. Specific elements on the agri-food chain of organic products were also analyzed, in relation to consumer demands and product assurance [6, 10,22].

At EU level, the European Commission has set a target of increasing by 25% the area cultivated in organic farming, within which cereals occupy an important place [21].

The study analyzed the dynamics of areas cultivated with cereals in an organic system in the world, in Europe and in Romania, in the 2013 - 2023 period.

## MATERIALS AND METHODS

The study analyzed the variation in areas with cereals cultivated in an organic system in the world, in Europe and in Romania. The study considered data recorded between 2013 and 2023. For the situation recorded in the world and in Europe, data recorded based on FiBL were accessed [30]. For the situation in Romania, data recorded in the MADR database were accessed [31]. In the study, several abbreviations were used for analyses and graphic representations, namely: area cultivated with cereals (organic system) in the world - A(W); area cultivated with cereals (organic system) in Europe - A(Eur); area cultivated with cereals in the organic system in Romania - A(RO).

Based on the values accessed from the databases (FiBL NR, MADR NR), ratios were calculated between the area cultivated with cereals in the organic system at the three levels of data approach, A(Eur)/A(W), A(RO)/A(Eur), and A(RO)/AW respectively). The positioning of the years in the study period was analyzed, in relation to the data recorded at the data approach levels. The variation of the area with cereals in the ecological system was analyzed in dynamics at each approach level, in relation to time (T, years). A ranking of the years was made based on the recorded data, with emphasis on Romania.

Appropriate mathematical and statistical data analysis tools were used [11].

## RESEARCH RESULTS

The area cultivated with cereals in an ecologic system in the world, in Europe and in Romania was analyzed for the period 2013 - 2023. Based on the data, the ratios between the area cultivated with cereals in Europe (A(Eur)) and the area in the world (A(W)), between the area cultivated with cereals in Romania (A(RO)) and the area in Europe (A(Eur)), and respectively between the area cultivated with cereals in Romania (A(RO)) and the area in the world (A(W)) were calculated. The values of the areas cultivated with cereals in the organic system during the study period (average annual values), and the values of the calculated ratios, are shown in Table 1. According to the ANOVA Test, the existence of variance was confirmed, and also the statistical safety of the data, Table 2.

**Table 1.**

**Area cultivated with cereal crops in an ecologic system, in the world, in Europe and in Romania, period 2013 - 2023**

| Year | Cereal crops area | | | Calculated ratio | | |
|---|---|---|---|---|---|---|
| | A(W) | A(Eur) | A(RO) | A(Eur/A(W) | A(RO)/A(Eur) | A(RO)/A(W) |
| | (ha) | | | Ratio | | |
| **2013** | 3435682 | 1854727 | 109105 | 0.5398 | 0.0588 | 0.0318 |
| **2014** | 3288991 | 1911845 | 102531.5 | 0.5813 | 0.0536 | 0.0312 |
| **2015** | 3889353 | 2232921 | 81439.5 | 0.5741 | 0.0365 | 0.0209 |
| **2016** | 4187874 | 2279155 | 75198.31 | 0.5442 | 0.0330 | 0.0180 |
| **2017** | 4464347 | 2529808 | 84925.51 | 0.5667 | 0.0336 | 0.0190 |
| **2018** | 4782363 | 2639748 | 114427.5 | 0.5520 | 0.0433 | 0.0239 |
| **2019** | 5018958 | 2957165 | 126843 | 0.5892 | 0.0429 | 0.0253 |
| **2020** | 5088503 | 3027517 | 134170.2 | 0.5950 | 0.0443 | 0.0264 |
| **2021** | 5480988 | 2947005 | 139378.2 | 0.5377 | 0.0473 | 0.0254 |
| **2022** | 5641202 | 2911927 | 160154.7 | 0.5162 | 0.0550 | 0.0284 |
| **2023** | 5730109 | 2806551 | 172283.8 | 0.4898 | 0.0614 | 0.0301 |

*Source: data for the world situation A(W), and data at the European level A(Eur) have as their source the FiBL database [30]; data at the Romanian level A(RO), have as their source the MADR database [31]*

**Table 2.**

**Anova Test results**

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| **Between Groups** | 2.11E+14 | 5 | 4.21E+13 | 275.5119 | 5.0993E-40 | 2.3683 |
| **Within Groups** | 9.17E+12 | 60 | 1.53E+11 | | | |
| **Total** | 2.2E+14 | 65 | | | | |

Based on PCA, PC1 explained 86.254% and PC2 explained 12.31% of the total variance, with the PCA diagram presented in Figure 1. For Romania, correlated with the area cultivated in the organic system, the year 2023 stood out, followed by the year 2022.

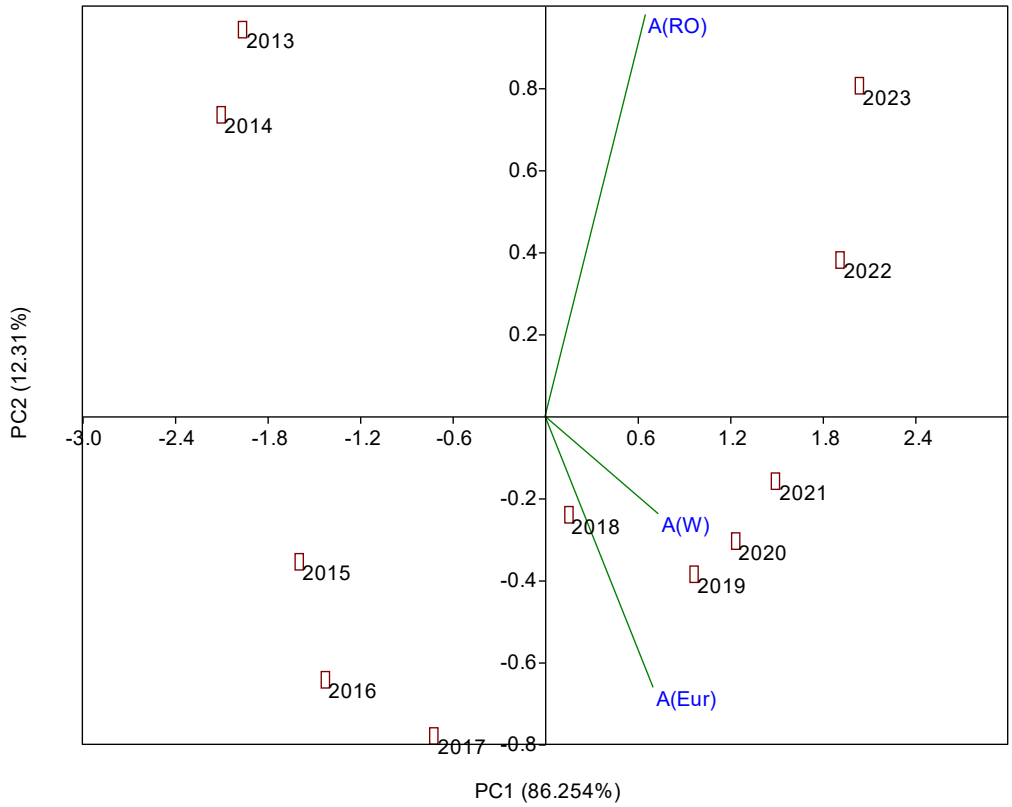
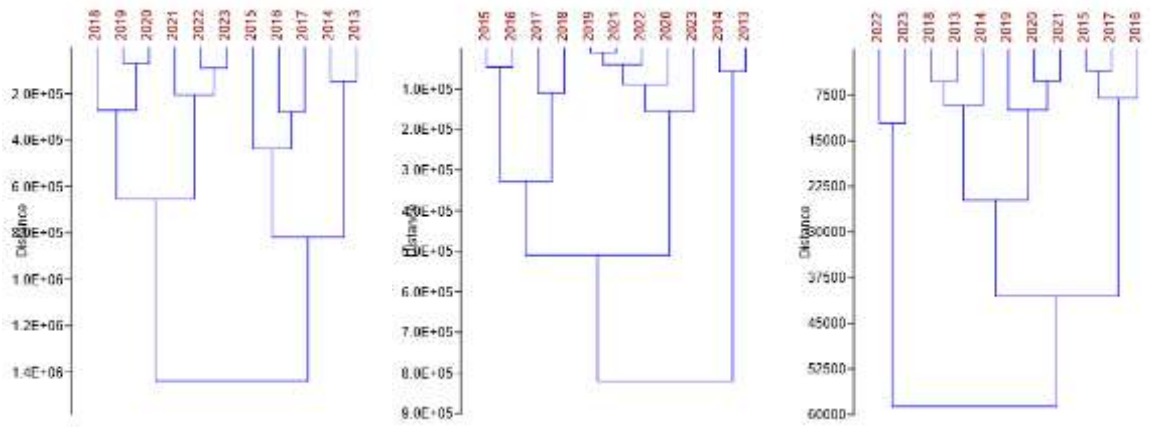



**Figure 1. PCA diagram based on the area of cereals in the organic system in the world, in Europe and in Romania during the study period**

Cluster analysis was applied to generate dendrograms regarding the area cultivated with cereals in the organic system in the world (Coph.corr. = 0.748), in Europe (Coph.corr. = 0.812), and in Romania (Coph.corr. = 0.760), Figure 2. Looking at the situation in the world, a dendrogram with two clusters resulted, quite balanced. One cluster comprised five years and the other cluster comprised six years, associated on the basis of similarity for the area of cereal crops in the ecological system, Figure 2(a). For the European situation, a dendrogram with two clusters resulted, with a disproportionate arrangement of years. One cluster included two years (2013, 2014), and the other years were positioned in the second cluster, in two distinct subclusters, Figure 2(b). In the case of Romania, the study years were positioned in two distinct clusters, with two years in one cluster, and the other years in the other cluster, with most of the years positioned in a subcluster in the central area of the dendrogram, Figure 2(c).




(a) (b) (c)

**Figure 2. Cluster dendrograms regarding the area with cereals in the organic system, period 2013 - 2023; (a) – in the world; (b) – in Europe; (c) – in Romania**

The variation in the dynamics of the area cultivated with cereals in an organic system in the world, in Europe and in Romania, during the study period was analyzed.

The distribution of the area cultivated with cereals in the ecological system in the world, in relation to time (T, years) during the study period, was described by a polynomial equation, with $R^2$ = 0.983, p<0.001, F=132.72. Figure 3 show the graphical distribution. The deviation from the function model was observed for the case of 2014 year, and the year 2020.

$$A = -1704.6x^3 + 1E+07x^2 - 2E+10x + 1E+13 \quad (1)$$

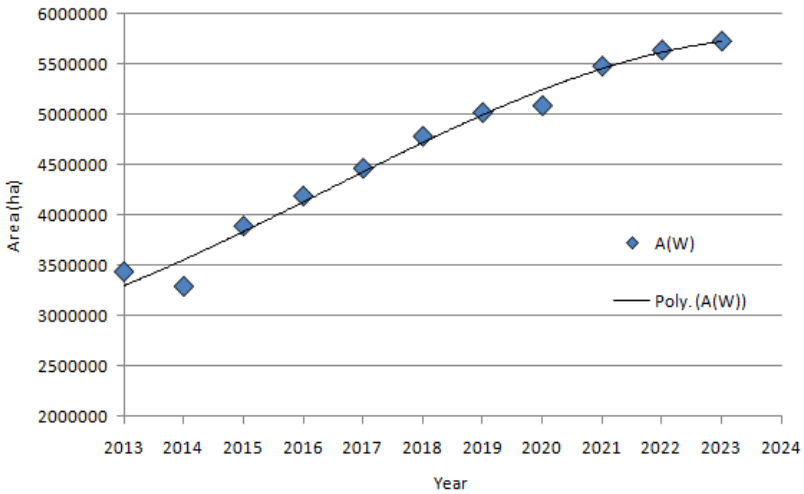



**Figure 3. Graphical representation of the values of cereal area in ecological systems in the world, during the study period**

The distribution of the area cultivated with cereals in the organic system in Europe, in relation to time (T, years) during the study period, was described by the polynomial equation (2), with $R^2$ = 0.980, p<0.001, F=113.11. The graphical distribution is presented in Figure 4. A maximum value was observed in 2020, followed by a decrease in the values.

$$A = -3176.2x^3 + 2E+07x^2 - 4E+10x + 3E+13 \quad (2)$$

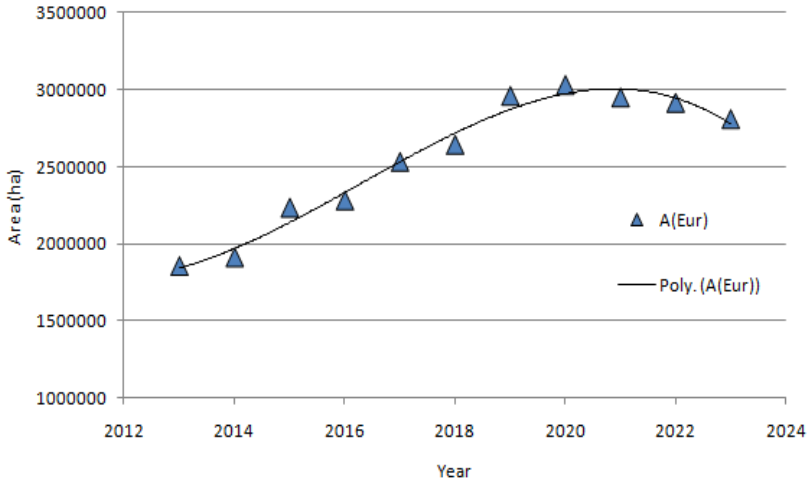



**Figure 4. Graphical representation of the values of cereal area in organic farming in Europe, during the study period**

The distribution of the area cultivated with cereals in the organic system in Romania, in relation to time (T, years) during the study period, was described by equation (3), under conditions of $R^2 = 0.946$, $p<0.001$, $F=40.978$, Figure 5.

$$A = -324.05x^3 + 2E+06x^2 - 4E+09x + 3E+12 \quad (3)$$

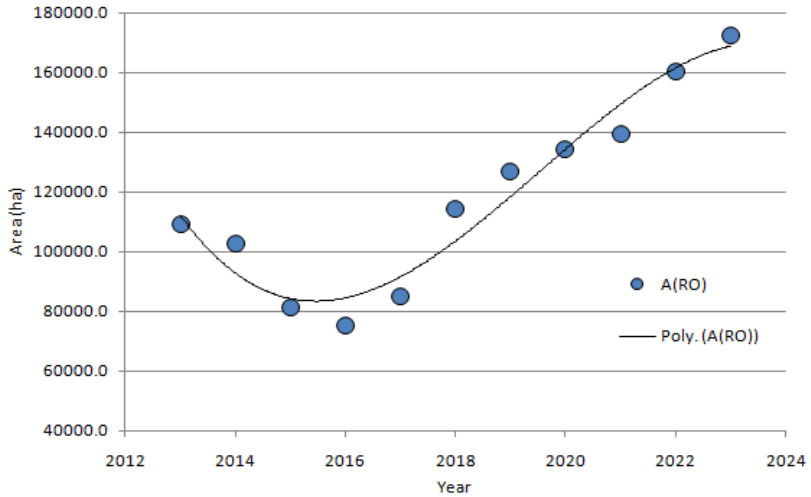
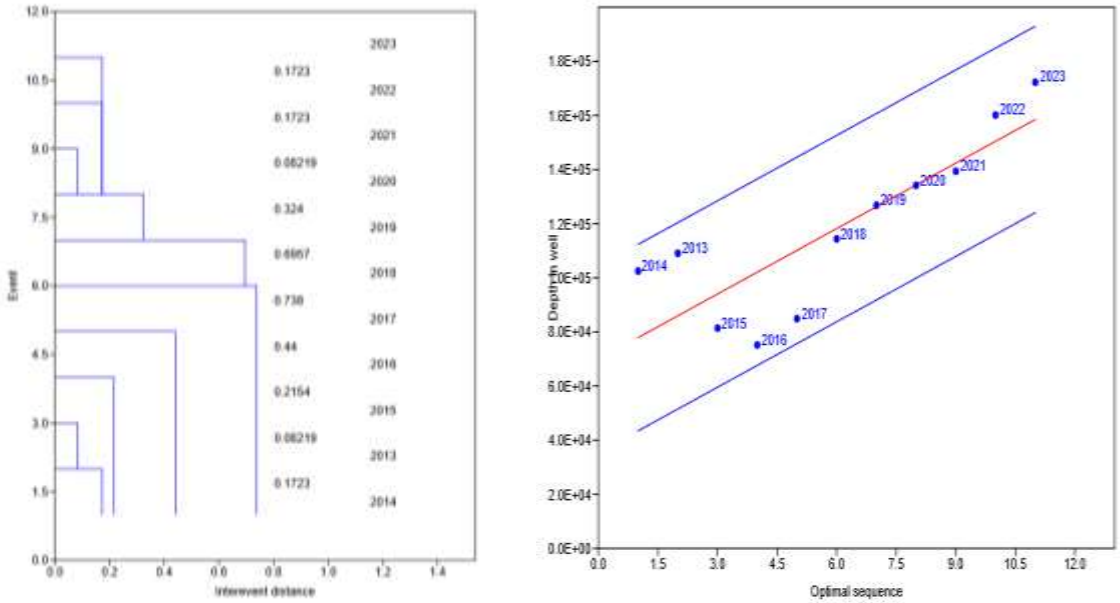



**Figure 5. Graphical representation of the values of cereal area in the organic system in Romania, during the study period**

A decreasing distribution of values was observed in the first part of the interval, with a minimum in 2016. An increase in the values of the areas cultivated with cereals in the organic system followed, with a tendency to reduce (slow down) the growth (flatten) at the end of the study interval (year 2023).

As a cumulative effect of the areas cultivated with cereals in the organic system, the ranking analysis placed the years in descending order, Figure 6(a). An inversion was recorded in the ranking diagram of the years 2013 and 2014. The year 2014 also presented deviations in the case of the models of equations (1) – (3), especially in the case of equation (1). The scattergram distribution of the years over the study period, for the situation in Romania, is presented in Figure 6(b).




(a) (b)

**Figure 6. Ranking diagram of the years during the study period (a), and scattergram diagram with the distribution of years for conditions in Romania (b)**

As a result of the high share of cereals in the structure of crop plants, studies were carried out to analyze, characterize and classify crops, which provided useful information for agricultural practice [12, 5, 9, 13]. Different methods have been applied to study areas cultivated with cereals in ecological systems, with practical utility for monitoring, and crop management practices in ecological systems [26, 27, 1].

The analysis carried out by this study showed the dynamics of the areas cultivated with cereals in the ecological system for the three reference levels, with the differentiated occurrence of fluctuations and the ranking of the years during the study period in relation to the elements considered.

## CONCLUSIONS

The variation of areas cultivated with cereals in an organic system in the world, in Europe and in Romania was described by polynomial models in relation to time during the study period 2013 - 2023. Certain deviations from the graphical distribution models of the equations were recorded for each level of data coverage.

The principal components explained 98.564% of the total variance. The PCA diagram presented the arrangement of years in relation to the data recording levels, and the cluster analysis showed the association mode based on the similarity of the years over the study period, for each data recording level.

From the situation in the world during the study period, a trend of stabilization of the growth of the areas cultivated with cereals in the organic system was observed. At the European level, a decreasing trend of the areas cultivated with cereals in the organic system was observed, after the maximum recorded in 2020.

In the conditions of Romania, a wide fluctuation of the areas cultivated with cereals in the organic system was recorded during the study period, with a minimum in 2016 and an increasing trend in recent years.

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