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Water Management of Czech Crop Production in 1961–2019

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Abstract: This study aims to evaluate the water balance of the crop mix of the Czech Republic and the tendencies of its development during the period 1961–2019. For calculating water deficits, methodology from ČSN 750434 (Czech technical standards) was used and on its basis, the deficits of the ten most frequently represented crops of the Czech Republic were calculated. These results were then put into the context of the development of precipitation totals and the development of average annual temperatures in the observed period. Furthermore, statistical tools were used for the identification of relationships between the observed variables and the tested hypotheses to verify the statistical significance of the observed changes. The results show that the overall irrigation deficit nearly doubled in Czech agriculture when comparing the averages for the periods 1961–1970 and 2010–2019. This change was evaluated as statistically significant. Furthermore, there were also statistically significant increases in water deficits in the cases of wheat, barley, rye, oats, legumes, and rapeseed. The sowing areas of the observed crops recorded statistically significant change in all cases. Only in the case of wheat, maize and rapeseed were there increases in sowing area, specifically 146%, 642.4%, and 1132.7%, respectively. For other crops, a decrease in sowing areas was observed. This finding points to decreasing commodity diversity in Czech agriculture, which, in combination with a high degree of intensification and selected agrotechnical practices, contributes to a lower retention capacity for the soil and landscape to retain water, which in turn influences the overall water balance of the Czech agrarian sector.

Keywords: water balance; Czech agriculture; crop mix; climate change; water deficit

Citation: Malec, K.; Gebeltová, Z.; Maitah, M.; Appiah-Kubi, S.N.K.; Sirohi, J.; Maitah, K.; Phiri, J.; Pańka, D.; Prus, P.; Smutka, L.; et al. Water Management of Czech Crop Production in 1961–2019. *Agriculture* **2022**, *12*, 22. https://doi.org/10.3390/agriculture12010022

Academic Editors: Ivan Francisco Garcia Tejero and Victor Hugo Durán-Zuazo

Received: 15 November 2021
Accepted: 23 December 2021
Published: 26 December 2021

1. Introduction

The issue of climate change has become topical in recent times. This is because of the impact of climate change on the environment and its inhabitants. Just as in other parts of the world, Europe also has its share in this phenomenon. European Commission (EC) [1] states that the occurrence of drought within the European Union (EU) has increased drastically in the past 30 years. People who have been affected by drought increased by 20 percent between 1976 and 2006. In the Czech Republic, temperature levels are continuing to rise [2].

According to the European Commission (EC) [3], water supplies have become a concern for almost half of the EU's population, even though Europe is not an arid continent by any means. Member states are wasting between 20% and 40% of their resources due to improper management. Faulty supply systems, dripping taps, unnecessary irrigation, and a lack of water-saving technologies installed in households and institutions across the EU all contribute to this situation. It is expected that water consumption in the public, agricultural and industrial sectors will increase by a total of 16% during the following decade.

The increasing demand for water along with a shortage in supply due to climate change will greatly affect the agriculture sector of the EU. The United Nations Food Agriculture Organization (UNFAO) asserts that there will not be enough water and food to meet demand by 2050 [4]. Water scarcity will become a global issue that will not just affect food prices but also promote inequality.

The importance of water in terms of agriculture production cannot be doubted. In their paper, Mozny et al. [5] studied past (1971–2018) and future (2021–2100) pan evaporation rates in the Czech Republic in the context of the recent multi-year of drought and significant losses of surface water deposits. They discovered that the vast majority of meteorological stations show a strong or very strong increase in pan evaporation (Epan) during April, June, July, and August and suggested that an increase in Epan would cause serious consequences for surface water availability and agricultural production during the periods of drought in the Czech Republic, as the drought period 2014–2018 has clearly demonstrated.

Trnka et al. [6] conducted a study on soil moisture trends in the Czech Republic between 1961 and 2012 using innovation to the standard methodological approaches in evaluating drought climatology by analyzing soil moisture conditions over more than 50 years. Their results showed that the probability of extreme drought events has increased and as such, the results support concerns about the potential increased severity of drought events in Central Europe under projected climate change.

In his study on increases in European severe and extreme soil moisture droughts under climate change, Grillakis [7] found that drought events are expected to increase regardless of the emission scenario and projected increases in European severe and extreme soil moisture drought events.

In view of the above, the question then arises of how these trends are expressed in the agrarian sector and if these trends affect the distribution of individual crops in the crop mix. The aim of this article is to evaluate the water balance of the crop mix in Czech agriculture during the period 1961–2019. For this purpose, a partial aim was established in the form of identifying changes in the representation of individual crops in the crop mix and their impact on the overall water balance in Czech agriculture for the observed time period. To achieve these aims, the following hypotheses have been established:

Hypothesis 1 (H1). *A statistically significant difference exists between deficits for individual crops in the crop mix for the periods 1961–1970 and 2010–2019.*

Hypothesis 2 (H2). *A statistically significant difference exists in the size of the sowing area for individual crops in the crop mix between the periods 1961–1970 and 2010–2019.*

Hypothesis 3 (H3). *There was a statistically significant change in the overall water balance in the observed crop mix between the periods 1961–1970 and 2010–2019.*

2. Materials and Methods

2.1. Study Area

The Czech Republic experiences different climate changes ranging from hot summer, cold winter, and chilly autumn. January usually records the lowest temperature around zero degrees Celsius characterized by strong cold winds and snowfall. During summer, the Czech Republic reported an average temperature of twenty degrees Celsius. However, the temperature can rise above thirty degrees Celsius in July, which is the warmest month in the Czech Republic. During this time, mountainous regions experience an average rainfall of 1600 mm while non-mountainous regions recorded an annual rainfall of 410 mm in the month of July. A report by the Ministry of Agriculture of the Czech Republic [8] showed that 54% of the total land area in the Czech Republic is used by entrepreneurs for farming purposes. Farmers engage in crop rotation, hop fields, fruit orchards, and grassland. Currently, the Czech Republic boasts 4.2 million hectares of farmlands with 71% of the land area consisting of arable land. Considering that arable lands are good for individual crop rotation, a decisive portion of the total agricultural land in the Czech Republic is used for the rotation of crops [8].

2.2. Data

The drought calculation comes from the methodology given by the standard ČSN 750434 [9] and data from the Czech Hydrometeorological Institute [10] on average monthly temperatures and precipitation in the Czech Republic during the years 1961–2019 serves as input data [10].

Data on the acreage of individual crops are then based on a survey by the Czech Statistical Office [11] Requirements for precipitation bringing optimum yield of selected crops are based on recalculations according to the representation of individual types of soil for a given region according to (ESEU) code, also called BPEJ in Czech [12,13].

2.3. Methodology

The methodology for achieving the aims listed above has two basic procedures. First, the water balance was calculated for the 10 crops most frequently represented on Czech agricultural land during the period 1961–2019. These are wheat, barley, rye, oats, maize for silage, legumes, rapeseed, sugar beet, potato, and fodder. The share of these crops reached 94.97% of the total area of agricultural land during the years 1961–1970 and 92.87% during the years 2010–2019 [14,15].

Basic comparative statistical methods were used for further evaluation of these results. Hypothesis testing was used to assess the plausibility of the set hypotheses and the normality of the set was first tested using the Kolmogorov–Smirnov test.

Where: $\hat{F}_n$ is defined for all real numbers x as follows:

$$F_n(x) = \widehat{\frac{1}{n}\sum_{i=1}^{n} I[X_i \leq x]}$$

Then Kolmogorov–Smirnov test to F_0 is:

$$KS = \sqrt{n}\max_{z}\left|\widehat{F_n}(x) - F_0\,(x)\right|$$

If the set showed a normal distribution, then the parametric test (paired t-test) was used to test the hypothesis.

$$t = \frac{\sum d}{\sqrt{\frac{n(\sum d^2) - (\sum d)^2}{n-1}}}$$

If the tested set did not show normal distribution, then the non-parametric test (the Wilcoxon test) was used.

$$Z = \frac{T_1 - \mu_{T_1}}{\sigma_{T_1}}$$

where $\mu_{T_1} = \frac{n_1(n+1)}{2}; \sigma_{T_1} = \sqrt{\frac{n_1 n_2(n+1)}{m}}$.

Statistical significance is tested at a 95% confidence level (α = 0.05) in all cases.

The correlation between individual variables was evaluated using the Pearson correlation coefficient, where values in the range of 0.7–0.9 are considered to have a strong correlation. Values between 0.5–0.7 then demonstrate a moderate correlation and values between 0.3–0.5 demonstrate a weak correlation. Ranges of values from 0 to 0.3 indicate an inconclusive relationship between variables.

Water deficit is presented in mm for individual crops and in cubic meters for the overall deficit, which is calculated as the sum of the water deficits of individual crops for the given year. Water deficit is recognized as lack of precipitation ensuring maximal (optimal) yields in respect to the observed temperatures. These data are calculated for the time period 1961–2019. Averages of the first and last observed decades, i.e., 1961–1970 and 2010–2019, are used to evaluate changes and their statistical testing. The averaged values result in the elimination of outliers and better identification of changes and their trend.

Water deficit/surplus for given crops is based on the Czech technical norm [9]. The norm uses the temperature standards (ST) based on the long-term temperature averages. Optimal rainfalls (OR) were determined for these standardized temperatures, see Table 1 These optimal rainfalls (in mm) are stated for the vegetation period (April–October) and they represent the sum of monthly precipitation which ensures maximal (optimal) yield for the given commodity [9]. The used variables are summarized in Table 1 below.

Table 1. Water requirements calculation.

Line	Crop/Item/Month	Unit
1	Temperature Standard (TS)	°C
2	Observed temperature	°C
3	Rounded to whole numbers (ROT)	°C
4	Temperature difference (td)(Line2–Line1)	°C
5	Optimal rainfall	mm
6	Adjustment1) for OR (aor)	mm
7	Adjusted OR (AOR) (Line5 + Line 4), Correspond with water requirement (WR)	mm
8	Observed rainfall	mm
9	Deficit d (−) /surplus water e (+) (Line7–Line6)	mm

Source: [9.10]. Note: For each +1 °C above the temperature standard, OR are increased by 5 mm; oppositely, for each −1 °C below the temperature standard, OR are decreased by 5 mm. These are represented by adjusted optimal rainfalls (AOR).

The obtained results show negative values when a water surplus was recorded or positive if there was a lack of rainfall and a water deficit was calculated.

Water deficit (WD in mm) is the sum of water deficits for observed months (d) in the given year. Water surplus (s) in one month can affect the water balance in the following month, thus the rainfall above the stated OR is transferred to the next month in the maximum value of |30| mm [9]. Then the DW is multiplied by the size of the harvest area (A).

The water deficit (DW) is calculated according to the following formulas:

$$\mathrm{WD} = \mathrm{WB} \times \mathrm{A}$$

where DW = water deficit, WB = water balance, A = harvest area of given crop

$$\mathrm{WB} = \mathrm{r} - \mathrm{AOR}$$

where WB = water balance, r = observed rainfall for a given period, AOR = Adjusted optimal rainfall

$$\mathrm{AOR} = \mathrm{aor} + \mathrm{OR}$$

where AOR = Adjusted optimal rainfall, aor = adjustment for optimal rainfall, OR = optimal rainfall

$$\mathrm{aor} = \mathrm{td} \times 5$$

where aor = adjustment for optimal rainfall, td = temperature difference between optimal and observed values

$$\mathrm{td} = \mathrm{ROT} - \mathrm{TS}$$

where td = temperature difference between optimal and observed temperatures in the given year, ROT = Rounded observed temperatures (to the whole numbers), TS = Temperature standard (according to the long-term average temperatures).

The method is based on a comparison of theoretical values of precipitation (OR) which should ensure maximal yield for the given crop in a given region with respect to the soil characteristics. These theoretical values of participation are suggested with respect to the long-term temperature averages (TS). If the observed temperature is different than stated long-term temperature averages (Table 2), then the theoretical value of precipitation (OR) has to be adjusted. The adjustment is + or −5 mm of precipitation for + or −1 °C from long-term temperature averages (TS). The difference between observed rounded temperatures (ROT) and long-term temperature averages (TS) is represented as "temperature difference (TD).

Table 2. Temperature standards.

Month	IV	V	VI	VII	VIII	IX	X
Normal temperature (°C)	9	14	17	19	18	14	12

Source: [9].

3. Results

Firstly, the development of average precipitation and temperatures was evaluated. Figure 1 does not show a significant trend in terms of annual precipitation totals. There are also many outliers from temperature normal, which are 685 mm of precipitation per year for the period 1961–1990, and 657 mm for the period 1981–2010 [10]. This corresponds to the variation range 363, which also indicates significant fluctuations in the observed measurements.

The situation is different for observed temperatures in a given period. Figure 2 shows the development of temperatures. Here, the increasing trend is clearly visible. The time series is again fluctuating considerably with a varied range of 3.3 °C for average temperature in individual years, where the temperature standard is 7.5 °C for the period 1961–1990 and 7.9 °C for the period 1981–2010.

The question then arises whether the increase in temperatures is significant enough to increase the water deficits for the crop mix (10 most common planted farm crops in the Czech Republic). Water deficits were therefore calculated for the 10 most frequently represented crops in the Czech crop mix and they were then compared with the averages of the years 1961–1970 and 2010–2019. In this way, the averaged values allow for the elimination of extremes and provide better information about the actual trend. Results including the difference between the first and last decades of the observed period are shown in Table 3, where a statistically significant change ($\alpha < 0.05$) is marked in bold.

Table 3. Comparison of deficits of individual crops for the first and last decades.

Crop	Average Deficit for Period 1961–1970 (v mm)	Average Deficit for Period 2010–2019 (v mm)	Sig. (Two-Tailed)
Wheat	4.2	29.1	0.009
Barley	3.5	28.9	0.013
Rye	1.4	24.0	0.008
Oats	9.8	39.8	0.025
Maize	6.5	21.9	0.173
Legumes	7.55	37.55	0.013
Rapeseed	10.3	35.9	0.009
Sugar beet	36.3	69.5	0.160
Potatoes	22.7	54.3	0.332
Fodder crops	23.7	59.6	0.081
Total Deficit in thousands of m^3	448,978.68	8,651,117.4	0.028

Source: Authors—based on CHMI [10].

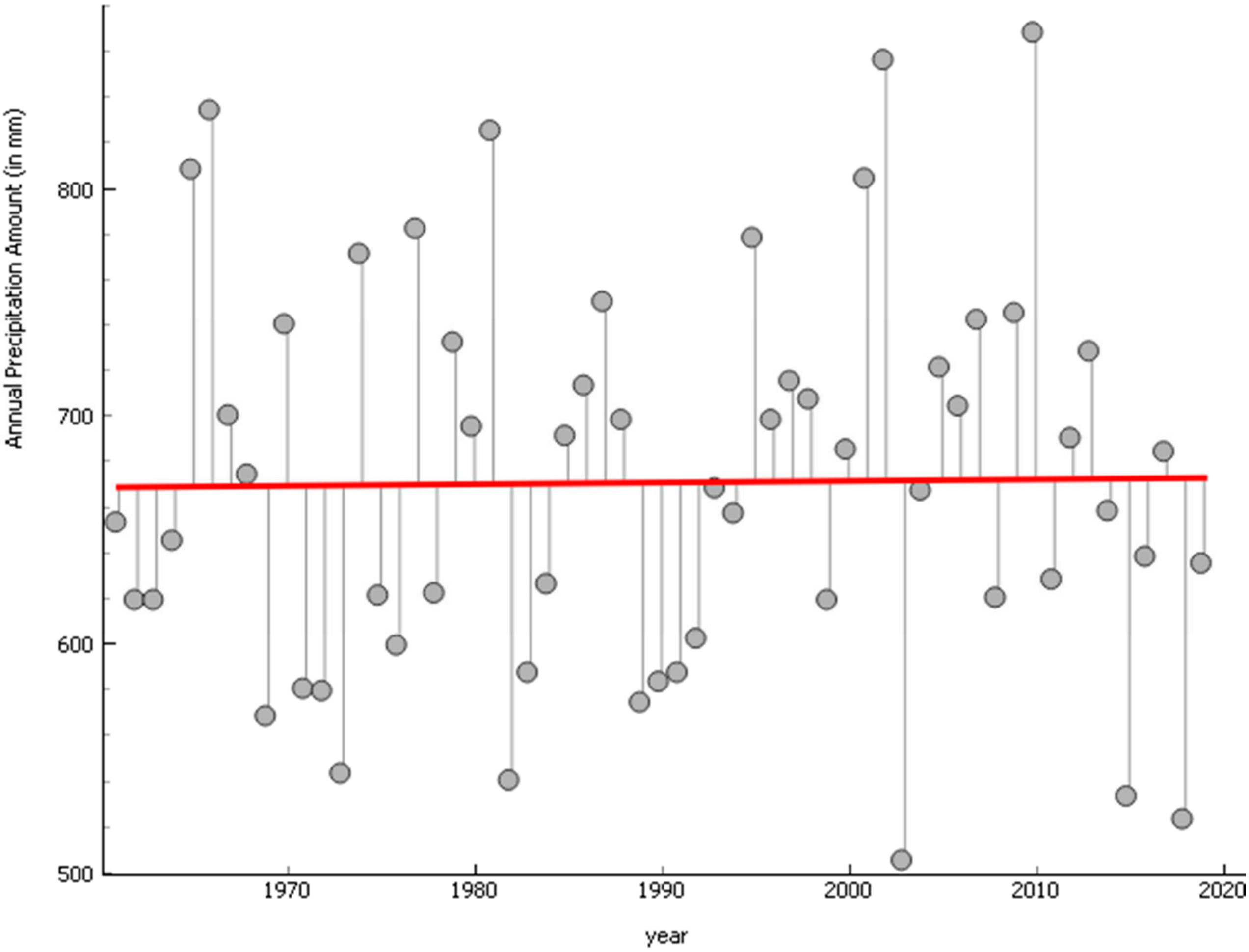

Figure 1. Yearly precipitation totals for the period 1961–2019. Source: [10].

The results show that the greatest increase in water deficits occurred in crops that showed lower deficits in the first observed period. In crops where the change is more than 3.5 times greater, the difference was identified as statistically significant. The difference between overall deficits for both observed periods was also identified as statistically significant.

Furthermore, the influence of temperature and precipitation on the overall deficit in agriculture in individual years was investigated. The influence of temperature on the overall deficit is shown in Figure 3.

Figure 3 shows the development of temperature over time, where the size of the bubbles reflects the size of the overall water deficit in agriculture in a given year and their color then reflects the average temperature for a given year. Here, it is seen that deficit correlates to increasing temperature. This also corresponds to Pearson correlation coefficient 0.516566 showing a moderate positive correlation.

The influence of precipitation on the overall water deficits is shown in Figure 4.

The Pearson correlation coefficient shows a weak negative correlation (−0.43191) between the development of yearly precipitation and the total Czech water deficit for the period 1961–2019. These values also correspond to the course of development of yearly precipitation, which is indicated with a color range, and overall water deficits, expressed by the size of individual points in Figurer 4. It is thus visible that the increasing water deficit in agriculture is mostly caused by increasing temperatures and their related evapotranspiration and greater demands on the water as one of the inputs.

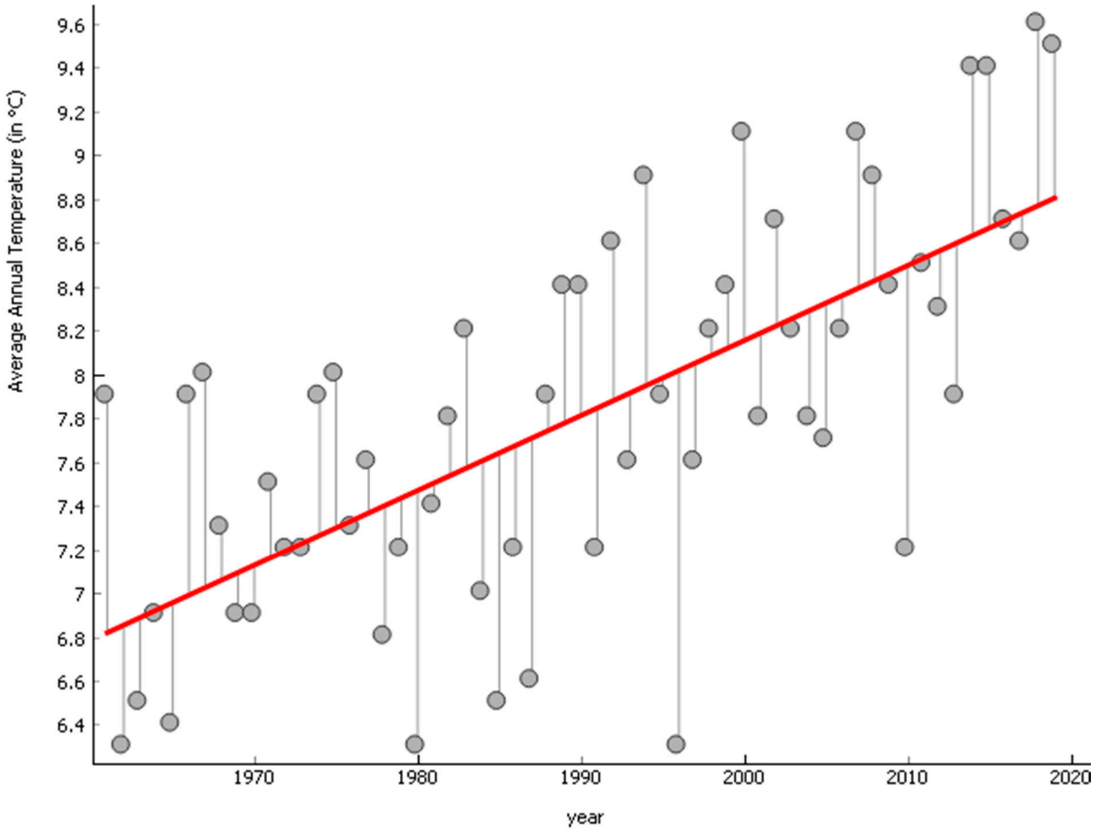

Figure 2. Average yearly temperature for the period 1961–2019. Source: [10].

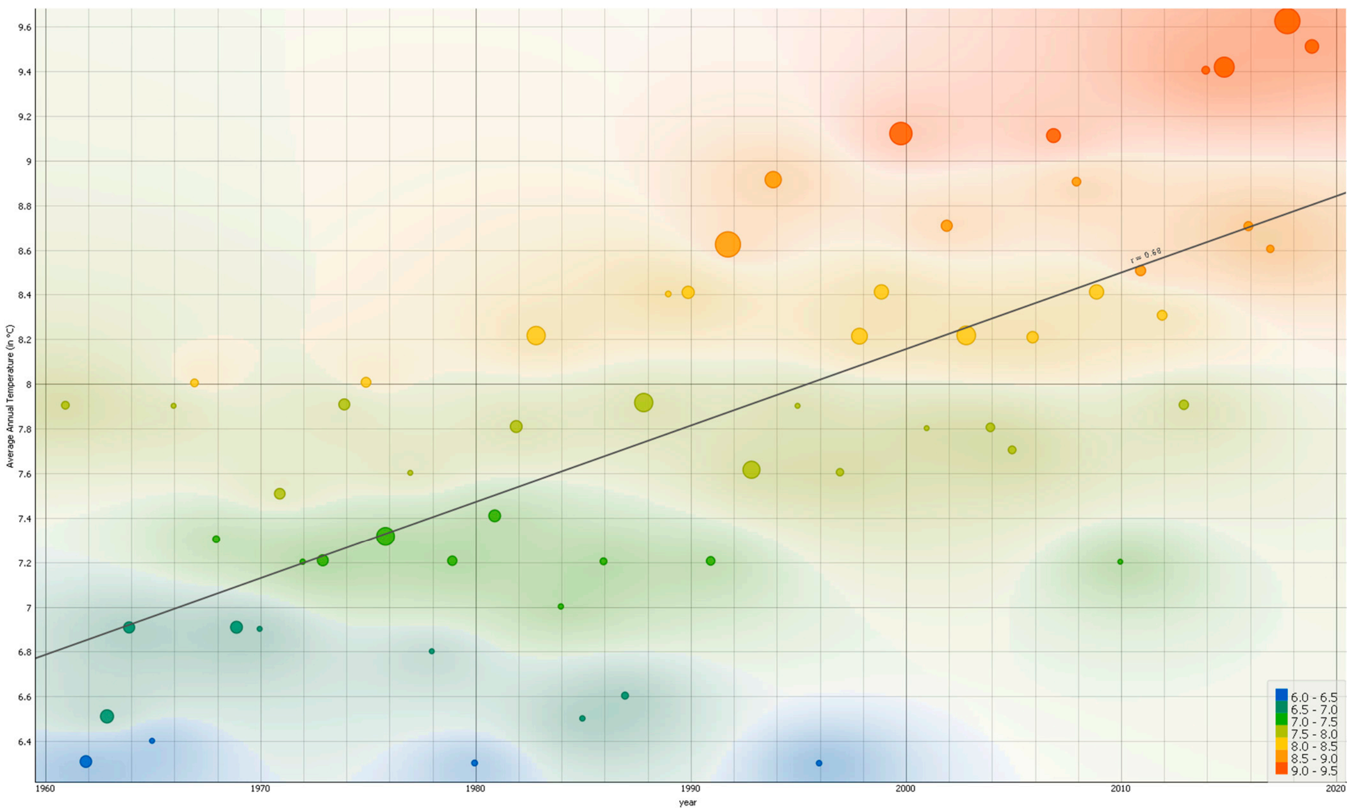

Figure 3. Development of overall water deficit over time in relation to temperature. Source: Authors—based on CHMI [10].

This relation is then further analyzed using Figure 5, which simultaneously shows the influence of temperature (horizontal axis) and rainfall (vertical axis) on overall water deficits in individual years scaled using colored indications and the size of individual points.

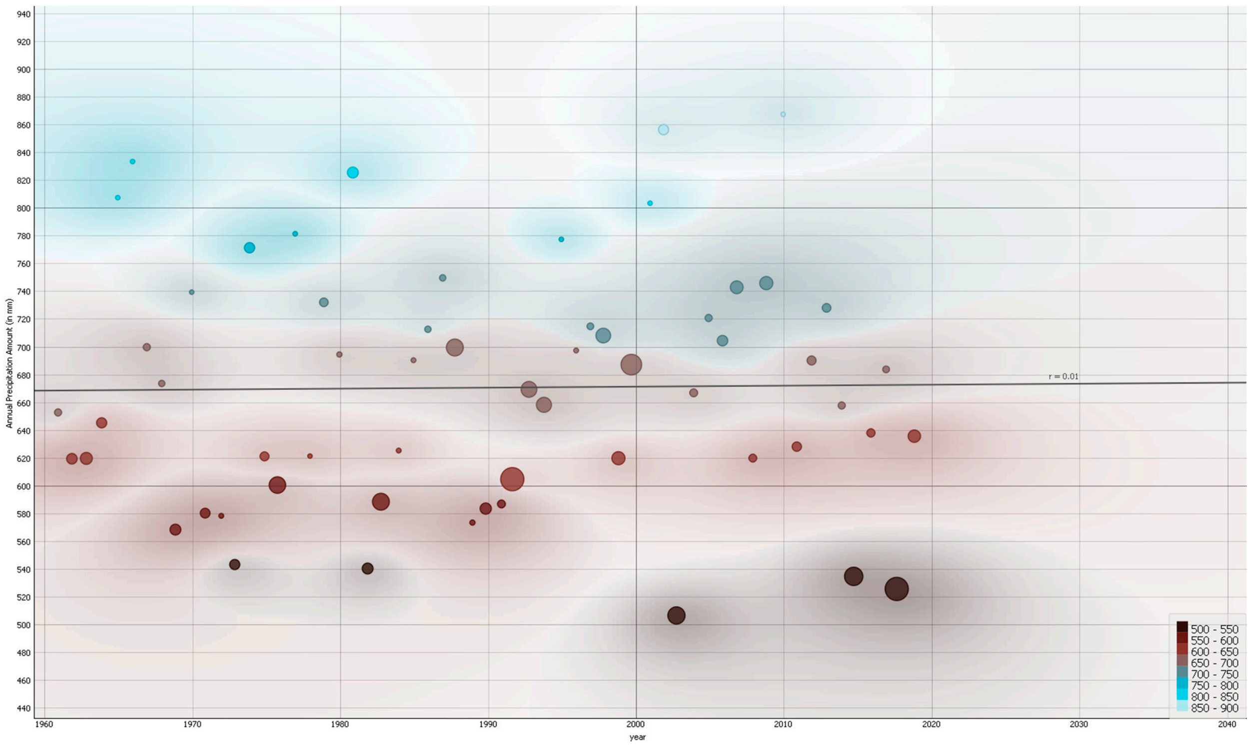

Figure 4. Development of overall water deficit over time in relation to total precipitation. Source: Authors—based on CHMI [10].

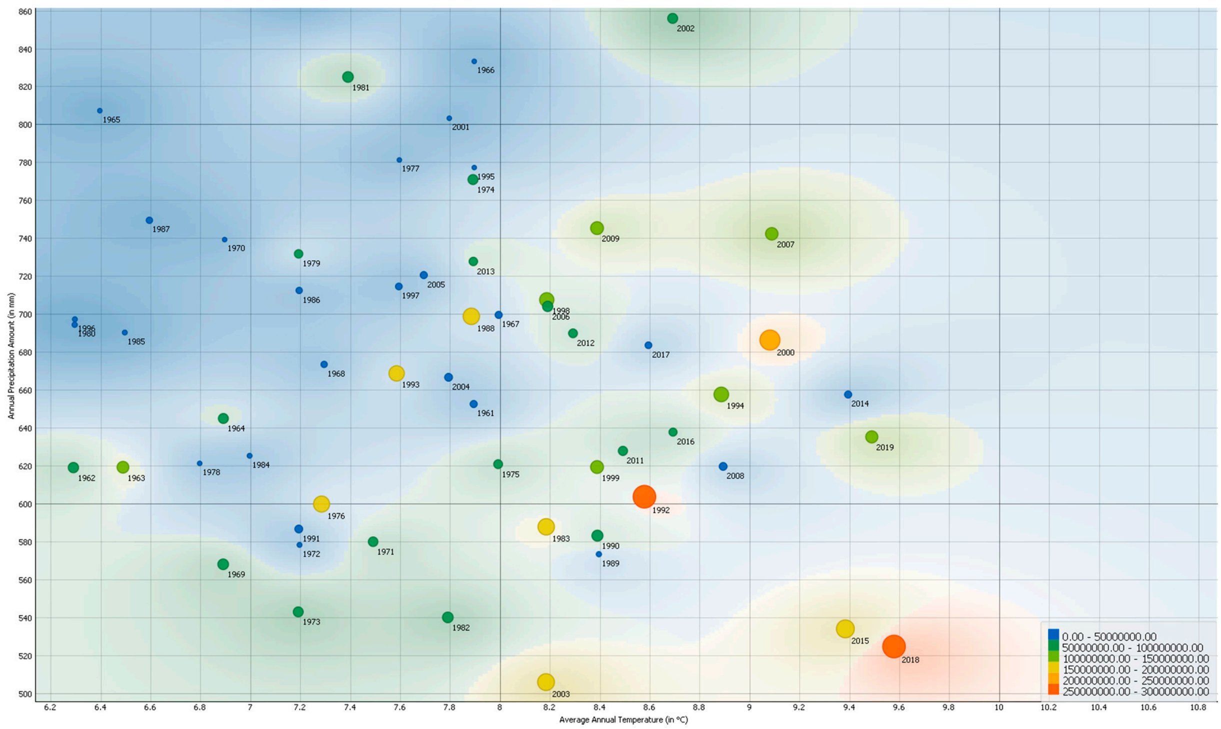

Figure 5. Development of overall water deficits in individual years in relation to precipitation and average temperature. Source: Authors—based on CHMI [10].

Figure 5 shows a clustering tendency on the left side, which again indicates the stronger influence of temperature on total water deficits. It is worth noting the years 1988, 1993, and 2000, when precipitation was close to, or even higher (1993) than the precipitation normal (697, 667, and 684 mm), and yet there were relatively high water deficits (173,677,668.5; 157,324,475.5; 225,472,406.5 m^3). The opposite extreme is then in 2019 when records show average temperature as well above normal and relatively little precipitation (9.5 °C and 634 mm), and yet this year resulted in relatively small deficit management (110,417,877.3 m^3). The explanation is the distribution of precipitation during the calendar year. A deficit for an agricultural crop is calculated only for selected months ranging from April to October. The authors of [16,17] agree that the months from April to June are the most sensitive period from the viewpoint of drought for cereal populations, and that spring cereals are generally more vulnerable to drought than the winter varieties, however, it depends on the course of the specific year, the initial soil water supply and the distribution of precipitation totals and the course of temperature. Therefore, if the year is below average in precipitation but with a large fluctuation in the vegetative months, a similar distortion may occur.

Changes in the acreage of observed crops for the period 1961–1970 and 2010–2019 are shown in Table 4. At the same time, the significance of these changes was statistically tested.

Table 4. Sowing area of selected crops for the first and last decades.

Crop	Acreage 1961–1970 (in Thousand ha)	Acreage 2010–2019 (in Thousand ha)	Change (in %) (Please Reduce the Decimal Places)	Sig. (Two-Tailed)
Wheat	570.8	833.8	146.07	0.000
Barley	404.9	350.7	86.62	0.017
Rye	306.2	27	8.82	0.000
Oats	321.7	44.4	13.79	0.000
Maize	14.7	94.6	642.45	0.005
Legumes	75.5	29.2	38.72	0.000
Rapeseed	34.4	389.7	1132.69	0.005
Sugar beet	156.4	61	38.98	0.000
Potatoes	298.7	24	8.02	0.005
Fodder crops	1014.3	453.0	44.7	0.000

Source: Authors—based on CZSO and SPKK [14,15].

The results show that there were statistically significant changes in sowing area for all observed crops. The relation between change in sowing area and average water deficits for the decades 1961–1970 and 2010–2019 is shown in Figure 6. The difference in water deficit for the two compared periods (the average for 1961–1970 and 2010–2019, in mm) is scaled and marked in the graph according to color distribution (horizontal axis). The size of the bubble corresponds to the difference in sowing area for a selected commodity (vertical axis).

It is clear from the graph that the sowing areas of crops with the greatest deficit decreased. Apparently problematic are increasing areas of wheat (+146%, Table 2) and especially rapeseed, where the area increased more than 11 times in comparison with the first decade (Table 2). In the case of rapeseed and maize, this growth is due to the fact that they were underrepresented in the Czech production mix of the 1960s.

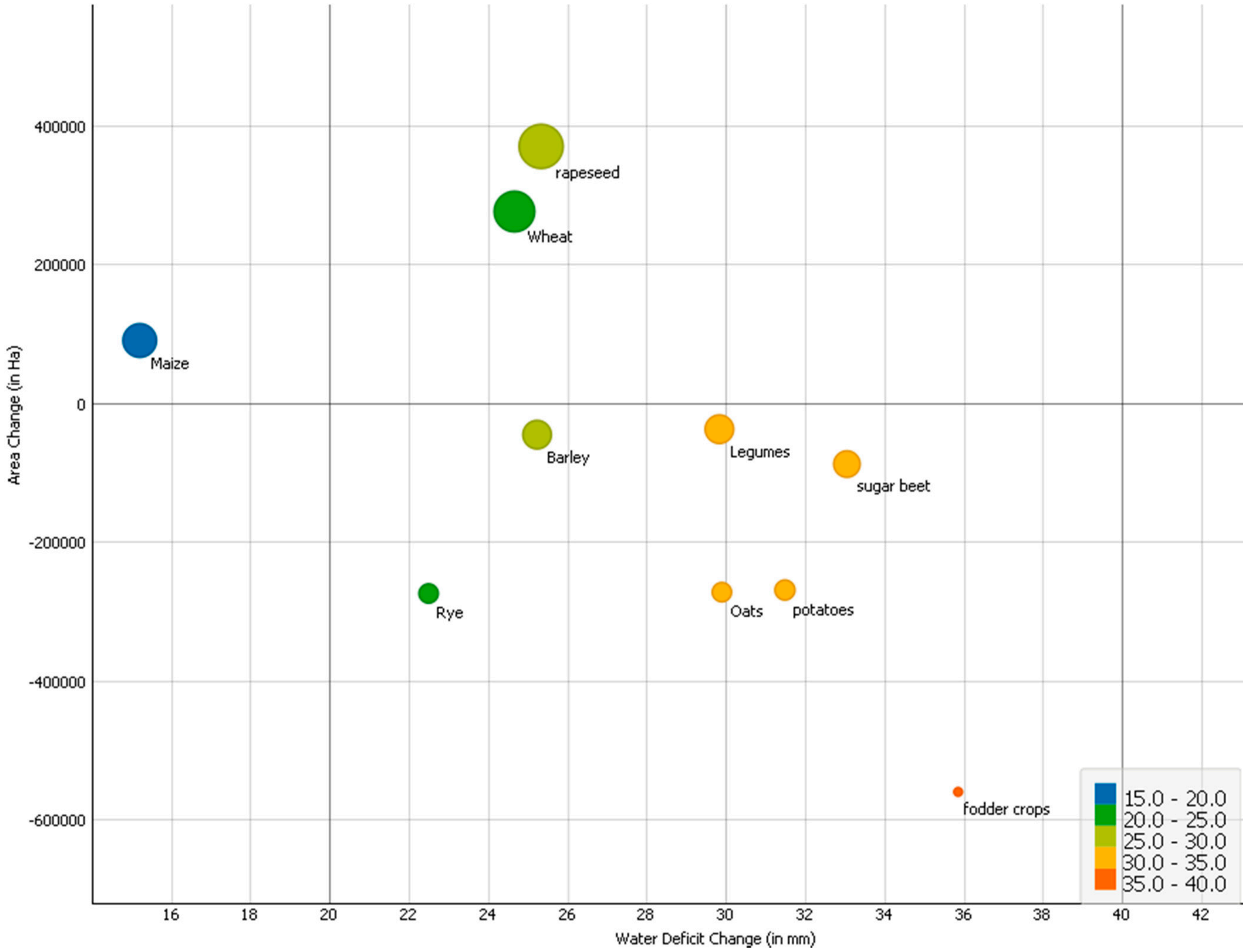

Figure 6. Changes in sowing area of observed crops in relation to changes in water deficit. Source: Authors—based on CHMI [10].

4. Discussion

Water is an essential input in the process of agricultural production and changing precipitation totals and, especially rising temperatures play a crucial role in increasing water deficits for the observed crops. Rising temperatures for the region of the Czech Republic are also documented by Zahradníček et al. [2].

Increasing evapotranspiration is associated with rising temperatures. Ref. [5] indicates a strong or very strong increase in evapotranspiration in April, June, July, and August for the period 1971–2018. This finding is crucial especially for April and June, when the majority of the crops from the observed crop mix require the most water.

The values nearly doubled (1.93) the increase in overall water deficit in agriculture during the compared periods 1961–1970 and 2010–2019. This change was then also confirmed as statistically significant.

For individual crops, the change in water deficits for the observed periods was statistically significant ($\alpha < 0.05$) for wheat, barley, rye, oats, legumes, and rapeseed. There was a significant increase in sowing area of wheat and rapeseed (+146.1% and +1132%, respectively, in comparison to the first observed decade).

Ref. [18] developed a method to simultaneously quantify severe water scarcity (SWS) over the world's entire wheat-growing area and calculate the probabilities of multiple/sequential severe water scarcity (SWS) events for baseline and future climates. Their projections show that, without climate change mitigation (representative concentration pathway 8.5), up to 60% of the current wheat-growing area will face simultaneous SWS events by the end of this century, compared to 15% today. Climate change stabilization in line with the Paris Agreement would substantially reduce these negative effects, but they would still double between 2041 and 2070 compared to current conditions.

Wheat was one of the observed crops in the Czech Republic with the lowest absolute average deficit for the last observed decade (29.1 mm) and growth of its sowing area can thus be described as changing proportionally with climate conditions. Procházková et al. [19] drew attention to a more complicated situation concerning the growth of rapeseed, emphasizing the negative impact its influence has on the landscape and soil quality when it is grown in large monocultures, which is typical in the Czech Republic, and the entire process burdens the ecosystem. On the other hand, rapeseed can be considered as a non-erosive crop that is capable of providing relatively large benefits even to soils with high salinity and relatively high sodium content [20]. The increasing acreage of rapeseed and the planting of new types of crops such as fast-growing woody plants for biomass are directly related to EU support for renewable resources and the parameters of its Common Agricultural Policy [21]. This support is increased for the last programming period. An emphasis on sustainable agriculture, green farming, etc., is also associated with this [22]. However, its impact on current market conditions leaves room for further analysis.

Furthermore, an increasing sowing area was also recorded for maize (+ 642%). This change, however, was not evaluated as statistically significant. According to McGregor et al. [23], maize is an erosive crop and increasing its area is not optimal in the view of soil management. Daryanto et al. [24] present a study from peer-reviewed publications between 1980 and 2015 on the global synthesis of drought effects on maize and wheat production using a data synthesis approach to better characterize the effects of those co-varying factors with drought and to provide critical information on minimizing yield loss. Their results revealed that maize was more sensitive to drought than wheat, particularly during the reproductive phase, and equally sensitive in dryland and non-dryland regions. On the other hand, maize exhibited the smallest absolute water deficit (21.9 mm) for the last decade from all observed crops. Its increase between the compared periods was then not evaluated as statistically significant at the level $\alpha = 0.05$.

On the other hand, crops with the greatest absolute water deficit in the last evaluated decade also showed significant declines in sowing areas. This concerns sugar beet (water deficit 69.5 mm, decreased to 38.9% of the original acreage), potatoes (54.3 mm water deficit, decreased to 8% of the original acreage), and fodder (59.6 mm water deficit, decreased to 44.7% of the original acreage). These crops showed the highest water deficits of all observed crops even in the first period. However, the interpretation that climate change is reflected in the choice of crop mix would probably be an oversimplification. Mozny et al. [25], who modeled scenarios for climate change and its influence on selected crops, concluded their findings with the claim that a significant role in determining a farmer's choice of crop mix is, above all, market conditions, i.e., price of commodities on global markets and EU CAP instruments. Wheat was the basis for sowing procedures because it has a wide range of applications, easy to store, and has a long shelf life. Similarly, rapeseed is significant both in the food industry as well as the downstream industry. Even for reasons of food safety, it cannot be assumed that they will be significantly replaced by crops that demand less water in the crop mix. There are crops, however, that show higher resistance to climate change such as millet, oats, or sweet potatoes, and should therefore occupy a larger place in the crop mix [26]. Kotyza et al. [27] reported increasing yields for sugar beets in the Czech Republic. These then result from a greater amount of inputs (fungicides, applications of nitrogen fertilizers, growth stimulators) that bring further intensification to agricultural production.

However, the appropriate choice of crop mix and sowing procedures is essential from the viewpoint of soil quality and its water retention capacity [28]. This fact is gaining in importance especially at present time, when we are facing climate changes and expecting an increase in drought periods regardless of which future emission scenario is considered [7,29].

Thus, the management of soil water reserves proves to be crucial [30]. The need for greater diversification of crops grown in smaller units is indicated by Možný et al. [25] and Gebeltová et al. [31]. Kim et al. [32] confirmed this result and points to the importance of diversity and the cultivation of auxiliary crops in relation to microbiome diversity. This is also confirmed by Wu [33] who highlights the use of microbial inoculants to improve soil properties. The quality of the soil is directly related to its retention capacity. The microbiome and soil fauna play a role that links back to the used agrotechnical procedures [34].

In agriculture, even the application of modern natural or synthetic materials and new varieties can influence the water management of crops. Morphoregulators are used in the growing of cereals or oilseeds. Morphoregulators are used to shorten, and thus strengthen the stalks. These stalks are then more resistant to lodging, frost, etc. Morphoregulators also support the tillering of cereal stalks and increase the amount of grains in the ears [35]. Besides morphoregulators, short-stalked genotypes of wheat also appear. Even these varieties are characterized by high yields. The water demand for these crops is not lower. Support of root branching during long droughts is counterproductive. Dense vegetation will deplete the previously available water supply more quickly and the tillers will dry out. In the case of drought onset, it is advisable to stop applying stem-shortening morphoregulators [36].

To mitigate the impact of drought, no-till cultivation of land that has cover crops is also recommended. This leads to improved soil structure, limited erosion, and a heightened retention capacity of the soil in dry areas. This is confirmed by research in the Czech Republic, as well as in Australia and Spain [37–40]. On the other hand, when soil tillage is minimized, weed and pest growth increase [41–43]. Potential adaptation measures that can reduce the impact of drought on soil moisture may include the cultivation of several varieties of wheat and maize [44]. It has been found that combination farming of functional types of plants, which improves the resilience of the ecosystem, mitigates the negative effects of mild and extreme drought events [43]. The role of incorporating animal or plant bi-products back into the soil is discussed, e.g., by Aslam et al. [44], who investigated the use of vermicompost from straw and other organic residuals in wheat production.

5. Conclusions

The aim of this article was to evaluate the water balance in Czech agriculture for the 10 most often represented Czech crops in the years 1961–2019. The results show that the overall water deficit has nearly doubled. Increases in average temperature and evapotranspiration are mainly responsible for this growth. This influence was confirmed as a moderately strong correlation (Pearson correlation coefficient 0.516566). The correlation with annual precipitation totals was then weakly negative (−0.43191). The most water-intensive of the observed crops is sugar beet (average deficit 69.5 mm precipitation for the period 2010–2019), potatoes (average deficit 54.3 mm precipitation for the period 2010–2019) and fodder crops (average deficit of 59.6 mm precipitation for the period 2010–2019). Conversely, the lowest water deficits were calculated for maize (average deficit 21.9 mm precipitation for the period 2010–2019), rye (average deficit 24 mm precipitation for the period 2010–2019), and wheat (average deficit of 29.1 mm precipitation for the period 2010–2019). However, crops with a lower deficit average showed statistically significant increases in water deficit when comparing the periods 1961–1970 and 2010–2019. This growth is primarily explained by these crops showing very low deficits in the first observed period.

The results of investigating the changes in sowing areas show a statistically significant change in all observed cases. This is probably due to several factors including a decrease in the amount of farmland, change in sowing procedures, and the development of Czech agriculture in the selected time frame. The biggest increase in sowing area was recorded for wheat (+ 146%) and rapeseed (+ 1132%). The biggest decrease in sowing area is seen in the cases of rye (to 8.8% of the original acreage), potato (to 8% of the original acreage), and oats (to 13.8% of the original acreage). This decrease is probably a reaction to changing market conditions.

From the point of view of representing individual crops, greater diversity and the use of favorable agrotechnical practices in relation to soil, landscape, and biodiversity is desirable. This can then influence the capacity of the soil and landscape to retain water. The setting of the agricultural policy of the EU and individual member states should correspond to these recommendations. This aspect then opens a space for follow-up research.

Study Limitations: Calculated water deficits are based on ČSN (Czech technical standards), which is a simplified model for calculating the water needs of individual crops. These results thus provide information on the water deficit in Czech agriculture for the observed period. However, individual regions and districts can show great variability, which will be influenced by many other factors.

At the same time, the comparison of sowing areas is influenced by the fact that the amount of agricultural land is constantly decreasing. The influence of sowing areas and changing climate conditions is illustrative and provides space for further research.

Author Contributions: Conceptualization, K.M. (Karel Malec); M.M. and Z.G.; methodology, K.M. (Karel Malec); J.S. and J.P.; software, S.N.K.A.-K.; P.P. and K.M. (Kamil Maitah); validation, K.M. (Karel Malec); M.M.; D.P.; L.S. and J.J.; formal analysis, K.M. (Karel Malec); S.N.K.A.-K. and J.P.; investigation, Z.G.; M.M.; K.M. (Karel Malec) and J.S.; resources, K.M. (Kamil Maitah); P.P.; D.P.; L.S. and J.J.; data curation, K.M. (Karel Malec); K.M. (Kamil Maitah); S.N.K.A.-K. and J.S.; writing—original draft preparation, K.M. (Kamil Maitah); Z.G.; M.M.; P.P. and L.S.; writing—review and editing, S.N.K.A.-K.; K.M. (Karel Malec); J.S. and Z.G.; visualization, K.M. (Karel Malec); M.M.; K.M. (Kamil Maitah) and D.P.; supervision, M.M.; P.P. and J.J.; project administration, K.M. (Karel Malec); S.N.K.A.-K. and J.P; funding acquisition, K.M. (Karel Malec); M.M. and Z.G. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the Internal grant agency (IGA) of the Faculty of Economics and Management, Czech University of Life Sciences Prague, grant no. 2019B0011 "Economic analysis of water balance of the current agricultural commodities production mix in the Czech Republic" (Ekonomická analýza vodní bilance stávajícího produkčního mixu zemědělských komodit v ČR).

Acknowledgments: This work was supported by the Internal grant agency (IGA) of the Faculty of Economics and Management, Czech University of Life Sciences Prague, grant no. 2019B0011 "Economic analysis of water balance of the current agricultural commodities production mix in the Czech Republic" (Ekonomická analýza vodní bilance stávajícího produkčního mixu zemědělských komodit v ČR).

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

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