

# Intellectual Analysis of Major Crops Area due to Climate Changes in Ukraine

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**Abstract**— As a result of climate change in agriculture, certain changes are taking place that affect the economic component of Ukraine in the domestic and foreign markets. The statistical analysis of the time series of the majority crops areas for 22 years (from 1998 to 2020) is carried out, and also the influence of agroclimatic zones on the area of cultivation of the main crops is analyzed.

**Keywords**—climate changes, major crop area, statistical analysis, crop type classification map

## I. INTRODUCTION

Agriculture is the most important sector of the Ukrainian economy, and in the period from 2005 to 2012 its contribution to the country's gross domestic product averaged 10% [1].

Agricultural production largely depends on weather conditions and, as a consequence, on long-term trends and changes in climatic conditions [2]. High weather variability contributes to significant fluctuations in yields, which is observed in Ukraine, and climate change increases the production risk and threat to future crop production due to changes in temperature, regime and amount of precipitation and more and more occurrence of extreme weather events. Historical climatic data indicate an increase in temperature on the territory of Ukraine, and climate forecasts suggest further warming, especially in the south of Ukraine. Climate winters have different effects on yields due to precipitation and extreme temperatures [3]. For example, abnormal events such as freezing temperatures in autumn or intense heat in spring can lead to significant losses in wheat yield [4]. It is also known that worldwide extreme heat leads to a significant decrease in cereal yields [5], and there is strong evidence that the frequency of extreme events in the near future will increase in many regions of the world [6].

However, Ukrainian agriculture may also benefit from climate change in some regions due to higher winter temperatures and increased winter precipitation, a longer frost-free season and higher CO<sub>2</sub> concentration [7]. Accordingly, arable land may expand, especially in the north of Ukraine, but such projections are currently not clear enough.

Considering the above, the main purpose of this study is to assess the impact of changes in weather parameters on yield

and changes in the total area of each of the majoritarian crops in Ukraine.

In Ukraine, the continental climate is accompanied by hot summers and cold winters. The amount of precipitation is gradually decreasing and the temperature rises from north to south. About 48% of the country's territory contains highly fertile chernozems and mainly in the southern regions [8].

Climatic and soil conditions make it possible to divide Ukraine into three main climatic zones characterized by different ecological conditions that are important for agricultural production [9]: mixed forest, forest-steppe and steppe (Fig. 1). Two other zones in Ukraine, namely the Carpathians in the west and the Crimean mountains in the south, were not considered in this study due to the very low amount of cultivated areas.



Fig.1 Climate zone changes in Ukraine

In comparison with the current climatic norm, the average annual temperature is kept at the level of 1-2 degrees above the norm every year. According to the report of the experts of National Academy of Sciences of Ukraine, in recent decades there has been an actual shift of the country's natural and climatic zones by 100-150 km to the north. Vegetation conditions in the traditional subzone of the Northern Steppe (Dnipropetrovsk, Kirovohrad regions, etc.) in recent years already correspond to the subzone of the Southern Steppe [10].

Gradually, the steppe part of Ukraine climates closer to the dry subtropics, such as Greece. This is not a desert, and no longer a steppe. If the current trends of climate change continue in the next 20 years, it will be a real danger of actual loss for intensive agriculture, not only the steppe zone, but also more than half of the cropland of Ukraine.

According to research by the Chinese Academy of Agricultural Sciences [11] there is a negative trend between the yield of major crops and the average maximum and minimum temperatures during the crop growing season. That is why farmers are forced to change the range of crops they used to grow, because it is not possible to change the territory or move together with the climatic zone.

However, the climate change can also have another consequence for the agricultural sector. Thus, in recent years, Ukraine has created conditions for growing two crops in one season and not only in the southern but also in the northern regions. These results were obtained by the Space Research Institute of National Academy of Sciences of Ukraine and State Space Agency of Ukraine (SRI NASU-SSAU), and they were given the opportunity to identify such trends using satellite data [12].

Satellite imagery make it possible to track changes in the land cover and draw certain analytical conclusions based on them. Based on satellite data, it is possible to create crop type classification maps and analyze how crops change in different climatic zones of Ukraine. Such changes are actually taking place, and the study has identified the areas with the greatest changes in crop areas and major crop types. This important economic indicator can be taken into account in public administration and statistics.

## II. INPUT DATA

For analysis of the dynamics of crop areas changes in relation to climatic zones have been used national statistical for 1998-2019, crop classification maps for 2016-2020, information on climatic zones in Ukraine for 2000 and 2020, as well as the contours of administrative units at NUTS2 level (regions).

### A. Climatic Zones

Information on climate change used data provided by Ukrainian Hydrometeorological Center [13]. The shift of climatic zones in Ukraine is shown on Fig.2.

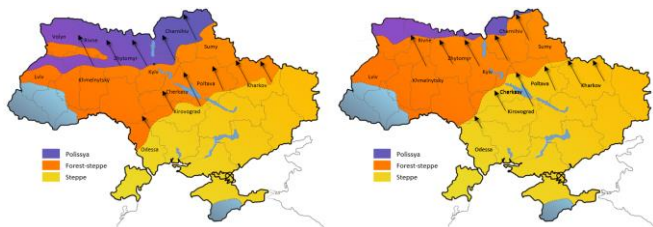


Fig.2 Climate zone changes in Ukraine

### B. Statistical Data

Official statistics data was used at district level for the main major crops in Ukraine (wheat, sunflower and maize) [5]. For 2019-2020, statistics for many districts are not available due to the reform of territorial boundaries.

The funding received by the National Research Foundation of Ukraine from the state budget 2020.01/0273 “Intelligent models and methods for determining land degradation indicators based on satellite data”.

Therefore, instead of statistical data, crop areas were used according to satellite information.

### C. Crop Type Classification Maps

As additional and auxiliary information for the analysis of sown areas the crop type classification maps for 2016-2020, which are received on own deep learning technologies based on satellite data by experts of the Space Research Institute NASU and SSAU are used. The used classification maps were obtained using open satellite data of the Copernicus program: SAR Sentinel-1 and optical Sentinel-2 with a spatial resolution of 10 meters. The maps were obtained within the framework of the World Bank projects and the EU-funded project “Support to Agriculture and Food Policy Implementation (SAFPI)”. To verify the reliability of the use of classification maps to assess the area, they were compared with statistics at the level of regions of Ukraine for 2016-2018.

### D. Administrative boundaries

Unfortunately, the state authorities of Ukraine have no official boundaries of administrative units. Therefore, within this study we were used boundaries from The Humanitarian Data Exchange (HDX) open platform for data sharing. The data has been provided by United Nations Office for the Coordination of Humanitarian Affairs in Ukraine.

## III. METHODOLOGY

To analyze the changes in the sown areas of the majority crops, the areas that were at the intersection of the changed climatic zones were identified. In Fig. 3 red lines show the desired zones of transition of climatic zones. Within these territories, areas were selected, 80% of the area of which fell within the transition of the climatic zone. The upper part (territory A) is a change of Polissya to a Forest-steppe, the lower part (territory B) is a change of the Forest-steppe to a Steppe. In the Table 1 are shown the regions separately for territory A and territory B.

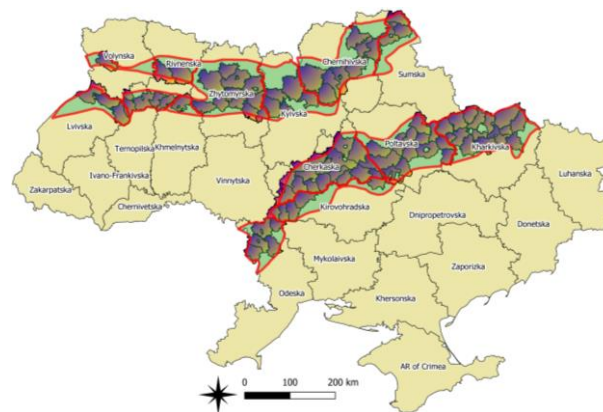


Fig. 3 Area of interest (areas at the intersection of climate zones that have changed and areas that have been located there)

As mentioned above, the statistics contain significant gaps in 2019 and 2020, so for a full analysis of the time series of data from 2000 to 2020 used sown areas for major crops, which were obtained from satellite data by deep learning algorithms. The areas obtained from the maps of the classification of crop types for 2016-2018 were compared with statistics.

After comparison the major crops areas on the classification map with statistical data and making sure that

they are reliable and can be used in further analysis, the analysis of statistical data with supplemented information on satellite data for 2016-2020.

TABLE I. REGIONS AFFECTED BY CLIMATE CHANGES

Oblast	Regions
<b>Territory A</b>	
Volyn	Turiyskiy
Zhytomyrska	Baranivskiy; Brusylivskiy; Khoroshivskiy; Yemilchynskiy; Korostenkyi; Korostyshivskiy; Luhynskiy; Malynskiy; Radomyshl'skiy; Pulynskiy; Cherniakhivskiy;
Kyivska	Borodianskyi; Brovarskiy; Vyshhorodskiy; K-Sviatoshynskiy; Makarivskiy
Lvivska	Brodivskiy; Radekhivskiy; Sokalskyi
Rivne	Demydivskiy; Dubenskyi; Zdolbunivskiy; Ostrozkyi; Radvyvylivskiy
Sumska	Seredyno-Budskiy; Shostkynskiy; Yampil'skiy
Khmelnyska	Slavutskiy
Chernihiv	Bobrovytskiy; Borznianskyi; Kozeletskiy; Koropskiy; Koriukivskiy; Nizhynskiy; Nosivskiy; Sosnytskiy
<b>Territory B</b>	
Kirovohrad	Haivoronskyi; Holovanivskiy; Novoarkhanhelskyi; Svitlovodskiy; Ulianovskiy
Odeska	Ananivskiy; Baltskiy; Podil'skiy; Oknianskyi; Savranskyi
Poltavska	Velykobahachanskyi; Hlobynskiy; Dykanskyi; Zinkivskiy; Karlivskiy; Kozelshchynskiy; Kotelevskiy; Kremenchutskiy; Poltavskiy; Reshetylvskiy; Semenivskiy; Chutivskiy; Shyshatskyi
Kharkivska	Bohodukhivskiy; Valkivskiy; V.Burlutskiy; Vovchanskyi; Derhachivskiy; Zmiivskiy; Zolochivskiy; Kolomatskyi; Krasnokutskiy; Novo-Vodolazkiy; Pechenizkiy; Kharkivskiy; Chuhuivskiy; Shevchenkovskiy
Cherkaska	Horodyschenskyi; Zvenyhorodskiy; Zolotoniskiy; Kam'ianskyi; Katerynopil'skiy; Korsun-Shevchenkivskiy; Lysianskyi; Mankivskiy; Smilianskyi; Talnivskiy; Umanskyi; Cherkaskiy; Chyhyrnytskiy; Chornobaivskiy; Shpolianskyi

#### IV. RESULTS

Comparison of statistical data with the obtained crop areas according to satellite data was performed using the metrics of statistical analysis correlation coefficient ( $R$ ) using the following formula:

$$R = \frac{\sum_{i=1}^n (s_i - s)(p_i - p)}{\sqrt{\sum_{i=1}^n (s_i - s)^2} \sqrt{\sum_{i=1}^n (p_i - p)^2}},$$

where  $s_i$  denotes statistical area of crops and  $p_i$  represents the area based on statistical data, respectively.  $s$  and  $p$  are arithmetic means of the statistical and satellite data, respectively, while  $n$  denotes the number of regions.

We will also be interested in the coefficient of determination  $R^2$  between statistical area of major crops and area based on satellite data:

$$R^2 = \frac{\sum_{i=1}^n (p_i - \hat{s}_i)^2}{\sum_{i=1}^n (p_i - p)^2},$$

where  $\hat{s}_i$  — simulated value of crops area based on time series statistical data.

The Fig. 4 shows the results of comparison the areas of major crops according to statistics and satellite data and shows

the corresponding correlation coefficients  $R$  and  $R^2$ . Analyzing these indicators, we can conclude that the classification these maps at the country level are reliable information and can be used for public authorities as additional information to the statistics on sown areas. This follows from the consistently high values of the correlation coefficient (0.8 - 0.9) and the regression indicator  $R$ -squared coefficient (0.7 - 0.8).

Analyzing the areas by major crops for two territories (A and B), several conclusions can be drawn. The first of these is illustrated in Fig. 5. Since 1998, in the Polissya zone, the area of maize and sunflower has grown significantly. Previously, agro-climatic conditions did not allow farmers to sow crops such as corn and sunflower in the Polissya zone, since these crops did not have time to reach the ripening stage when the temperature was insufficient. However, due to climatic changes, this has become possible, and even in some districts of the Lviv region, agrarians manage to get two crops per season from one field. Such a study was also carried out within the framework of the World Bank program and it was found about 4 thousand hectares of fields, which were harvested twice per season [12].

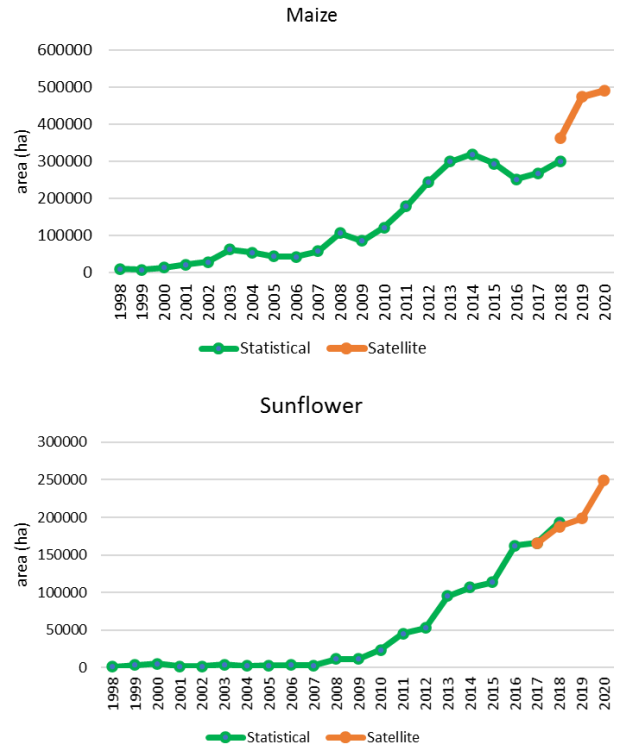


Fig. 5 Growth of sown areas of maize and sunflower in territory A from 1998 to 2020

However, under the conditions of climate change, winter crops are better. A positive factor for winter crops against the background of a general increase in air temperature, it has been noted in recent years, is relatively warm winters, which allow plants to successfully overwinter and even go through a certain stage in their development. Fig. 6 shows the areas in the studied areas for wheat for 1998 - 2020, from which it can

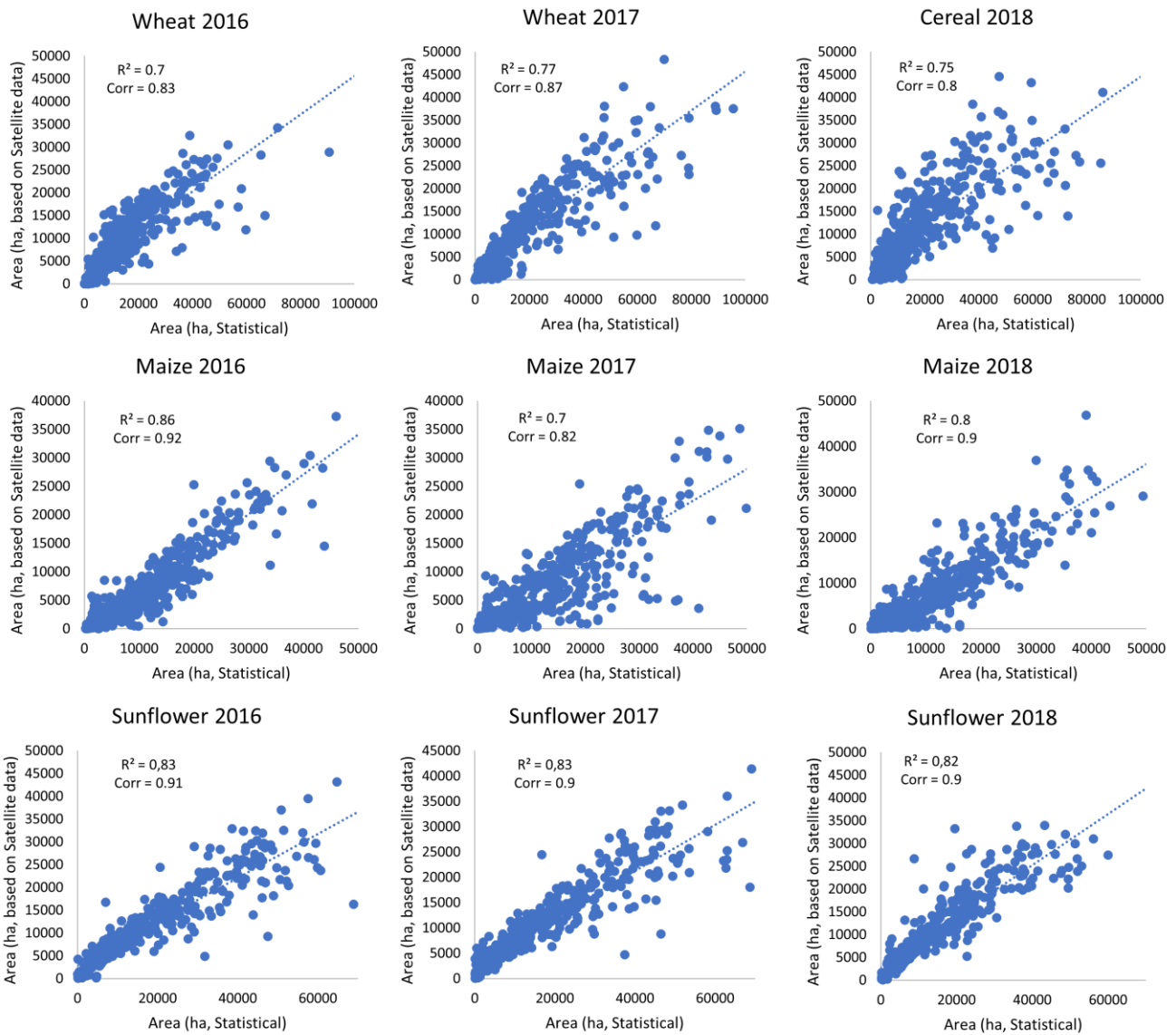


Fig. 4 Comparison of major crops area based on satellite data and statistical data by regions

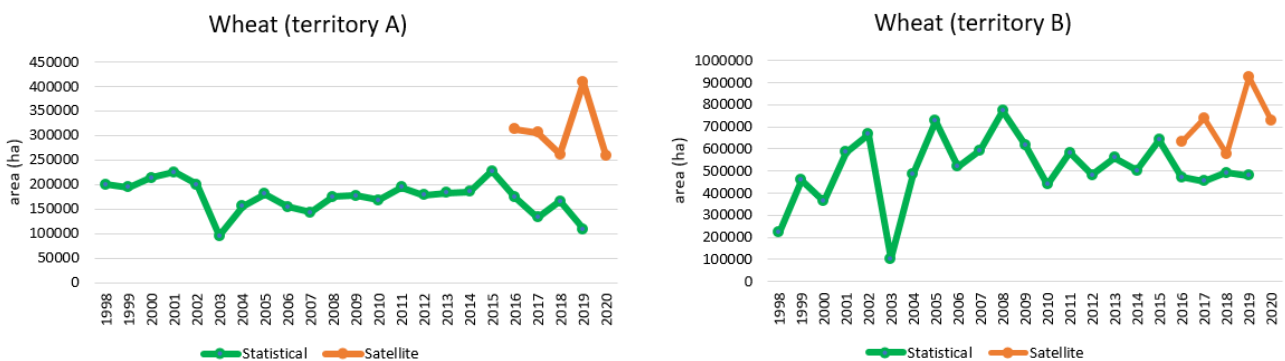


Fig. 6 Changes in wheat planted areas in territory A and B from 1998 to 2020

be concluded that for wheat there is no clearly pronounced tendency to change areas due to climate change [14]-[16].

### V. CONCLUSIONS

According to the results of the study, it can be concluded that in the study area A and B, the sown areas of maize and sunflower have increased. Based on the studies obtained and

the results of comparisons of statistical data with data on cultivated areas obtained from satellite information (classification map), it can be concluded that satellite information can be used as additional to statistical information and in cases where there is no statistical information. According to the results of the study, it can be concluded that in the study area A and B, the sown areas of corn and sunflower have increased. Based on the studies obtained and

the results of comparisons of statistical data with data on cultivated areas obtained from satellite information (classification map), it can be concluded that satellite information can be used as additional to statistical information and in cases where there is no statistical information.

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