Forecasting the area of agricultural and horticultural crops with the use of satellite remote sensing.

31.08.2021

1.35 million ha

Triticale area determined on the basis of an experimental method of crop identification based on satellite imagery in 2021.

Based on the experimental method of identifying crops using satellite imagery, the area of triticale in 2021 was determined at the level of 1.35 million hectares.

Project entitled **"Satellite identification and monitoring of crops for the needs of agricultural statistics - SATMIROL"** as part of the 1st competition for projects open under the strategic program of scientific research and development works - "Social and economic development of Poland in the conditions of globalizing markets - GOSPOSTRATEG"

Introduction

The study is a continuation of activities carried out in the field of experimental research in the thematic area of agriculture, the results of which were presented in the publication published in 2020 entitled "Application of satellite remote sensing in agricultural statistics to forecast the area of agricultural and horticultural crops".

Statistics Poland (GUS), together with the Statistical Office in Olsztyn, have for many years been carrying out activities aimed at using satellite imagery to forecast the area of agricultural and horticultural crops. These studies were conducted jointly with scientific units - The Space Research Center of the Polish Academy of Sciences (CBK PAN) and the Institute of Geodesy and Cartography (IGiK).

Additionally, in 2020, the Department of Agriculture of GUS continued work in the consortium with CBK PAN and IGiK and the Agency for Restructuring and Modernisation of Agriculture (ARMA) within the project “EOStat - Agriculture Poland”, which was founded by the European Space Agency where Statistics Poland was the main beneficiary. The experience of identifying crops, determining their area and yielding as well as monitoring crises in agriculture, which has been gained during the implementation of this project, will contribute to build a system for identifying and monitoring crops using satellite data.

Statistics Poland is a leader in implementing innovative methods of obtaining information. The main goal of the above mentioned activities is to build a system for identifying and monitoring crops with the use of satellite data. The permanent implementation of such system for statistical production will streamline the process of data collecting in the area of agricultural and horticulturally the possibility of extending the acquisition of data with spatial data on individual crops.

The use of satellite earth Observation Data (EO), will allow for more efficient use of administrative records (e. g. for segmentation of satellite imagery), faster obtaining of target data, including acquisition of low-level aggregated and spatially disaggregated data on agricultural/horticultural crops. This will reduce the burden on respondents and surveyors by excluding questions related to the cultivation of agricultural crops from surveys. Survey data will be replaced by data on agricultural crops obtained from processed satellite images without labor-intensive interviewing. Moreover, the system will allow for extending possibilities of result presentation by presenting them in form of maps, diagrams and carto diagrams for selected areas.

The introduction of an innovative system of identification and monitoring of agricultural crops will enable to acquire and present data in geospatial terms, which is not possible by the current data collections. The new method of obtaining data will make possible to present them at all levels of the country administrative division, namely, voivodships, powiats and gminas in accordance with the actual location of the land. Currently, collecting and presenting data at a lower aggregation level than voivodships is possible only for data obtained from full agricultural censuses carried out once every 10 years. However, these data allow for their aggregation according to the home address of a farm user or the address of a farm site. Satellite data, on the other hand, make it possible to present the results according to the actual location of the land.

The benefits from the implementation of the system also arise from the possibility of presenting data in spatial terms (not only in tabular, graphical and descriptive form) using the Geostatistical Portal as a tool for collecting, presenting and sharing information for a wide range of recipients, including public administration, entrepreneurs, individual users and scientific and research institutions. Data for the entire commune, district or voivodeship are indispensable for the proper shaping of development policies at the national and regional levels.

The system implemented within the framework of the SATMIROL project will also be one of the mechanisms for obtaining strategic data in the area of agricultural statistics, which will allow users to assess the situation in real time and to support activities within the framework of agricultural and agri-environmental policies, e. g. a policy of sustainable agricultural development based on rational use of plant protection products, mineral fertilizers and water. It will also improve the implementation of activities in the area of environmental protection and reduction of environmental degradation. It will also enable to monitor the current state of crops (droughts, floods). In summary, the new methodology and solutions adopted, based on the use of satellite data, will make it possible to provide data of better quality, in a shorter period of time and on a broader basis.

Preliminary estimate of the main agricultural and horticultural crops in 2021

The estimate was made using satellite remote sensing methods. It was based on Sentinel-1A/B radar images (13.9m resolution). The observation period covered the range from 15.03-15.07.2021. A total of 531 satellite scenes (4.5 TB data) of 250 km wide SLC (Single Look Complex) radar data and Sentinel-2 optical data (1 250 satellite scenes, 1.5 TB data) were used. The estimation was based on the segmentation and object-based image classification of the T2 coherence matrix and the polarimetric H/α decomposition parameters using machine learning algorithms (Random Forest). To teach the system and validate the classification results, we used data from the vector database of applications for payments obtained by the Department of Agriculture of the GUS from the Agency for Restructuring and Modernization of Agriculture. A land parcel mask was used to increase the precision of crop area mapping. An overall classification accuracy of 76% was obtained.

The detailed range of classification and accuracies obtained for each crop is shown in the table below:

Table 1. Detailed classification range and accuracies obtained for each crop

crop	area in [ha]	Precision*	Recall*	F-score*	OA*	KIA*
sugar beets	238 785	0,93	0,94	0,93		
charlock	52 153	0,72	0,27	0,39		
buckwheat	117 288	0,74	0,60	0,66		
spring barley	297 876	0,78	0,80	0,79		
winter barley	306 418	0,93	0,92	0,93		
corn	1 528 383	0,73	0,93	0,81		
cereal mixtures	353 633	0,55	0,46	0,50		
oat	413 251	0,60	0,69	0,64		
fruit tree plantations	316 474	0,82	0,80	0,81		
fruit shrub plantations	533 156	0,66	0,62	0,64		
millet	191 580	0,70	0,69	0,70		
spring wheat	338 060	0,60	0,40	0,48		
winter wheat	1 700 405	0,83	0,92	0,87	**0.76**	**0.75**
spring triticale	398 933	0,55	0,41	0,47		
winter triticale	954 882	0,75	0,85	0,79		
spring rape	154 889	0,64	0,23	0,34		
winter rape	859 993	0,90	0,98	0,94		
legumes	282 779	0,71	0,61	0,66		
grasses and grasslands	3 308 190	0,81	0,94	0,87		
strawberry	498 930	0,65	0,81	0,72		
tobacco	74 833	0,80	0,83	0,81		
vegetables	185 348	0,68	0,58	0,63		
potatoes	177 986	0,82	0,82	0,82		
herbs and spices	102 206	0,69	0,39	0,50		
rye	691 706	0,86	0,89	0,88		
Total	**14 078 136**					

Kappa coefficient was **0,75**

*Precision – ratio of correctly classified crops to the total number of classified objects in this class,
*Recall – ratio of correctly classified crops to the total number of control objects in that class,
*F-score – harmonic mean with precision and recall,
*OA (overall accuracy) – overall accuracy expressing the quotient of the sum of correctly classified objects and the total number of all classified objects
*KIA - kappa coefficient – expresses the total classification error. This factor determines how much better the classification has been done compared to random assignment of values. The kappa coefficient can range from -1 to 1. A value of 0 indicates that the classification is no better than a random classification. A negative number indicates that the classification is much worse than a random one. And value close to 1 indicates that the classification is much better than a random one."

Methodological notes and analysis of the results

a) In order to verify the obtained results, the area of crops recognized in 2021 in Poland and voivodships was compared with the area recognized in 2020, assuming that unless there were no significant losses in winter and permanent crops, it should not change significantly.

Table 2. Changes in the sown area in 2021 – in percentage

Cultivation	Poland	In voivodships
	2020=100	2020=100
sugar beet	87	30-131
charlock	21	5-47
buckwheat	34	5-106
spring barley	75	26-120
winter barley	94	41-127
maize	119	91-170
cereal mixtures	92	30-202
oat	57	28-102
fruit tree plantations	52	13-82
fruit shrub plantations	68	10-109
millet	130	11-374
spring wheat	86	22-269
winter wheat	115	85-155

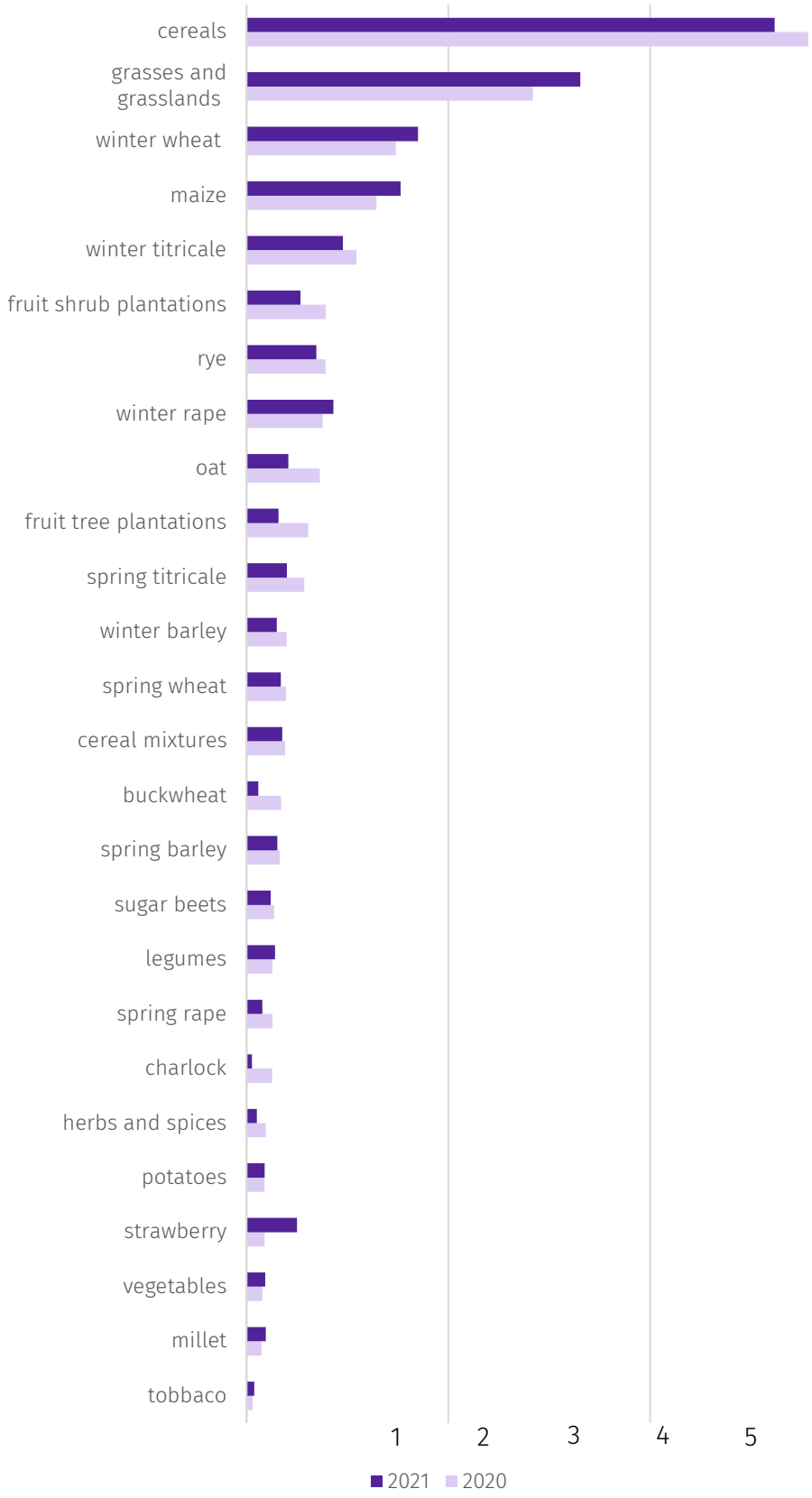
Changes in sown area Poland = **94%** (2020 = 100%)

Cultivation	Poland	In voivodships
	2020=100	2020=100
spring triticale	70	28-115
winter triticale	88	34-113
spring rape	61	10-124
winter rape	114	71-208
legumes	110	21-163
grasses and grasslands	117	106-156
strawberry	281	98-1 000
tobacco	125	2-754
vegetables	118	41-214
cereals*	90	69-117
potatoes	100	30-191
herbs and spices	53	6-134
rye	88	21-114
Average	**94**	**73-130**

*cereals – cereals similar in shape

- Due to unfavourable weather conditions and the consequent delay in spring fieldworks, a decrease in the total area under basic cereals (similar in shape) was observed this year - 90%. This is especially true for spring forms of all species. Their place was taken by maize, which is sown at a later agrotechnical date - 119%. The increasing area under maize cultivation is also a result of feed production for livestock and the growing consumption of raw material in bio-gas plants.
- This year, very many farmers decided to grow winter wheat, mainly con-consumption wheat at the expense of fodder cereals - 115%. They were persuaded to do so by the high and stable price of the raw material Therefore, the area of winter triticale - 88%, rye - 88% and winter barley - 94% decreased.
- There is a systematic increase in the area of winter rape cultivation in Poland - 114%. This is mainly related to the increased raw material demand of the oil industry. Besides, it is an excellent forecrop for winter wheat cultivation.
- A decrease in the area of sugar beet cultivation was observed - 87%. However, it must be taken into account that this may be related to the misdifferentiation of this crop in its early stages of development (as vegetables, maize, potatoes). In order to obtain higher accuracy, it is necessary to extend the time series of the radar data.
- The potato cultivation area is stabilized - 100%.
- There is a systematic increase in the acreage of leguminous crops in Poland - 110%, which have a beneficial effect on the physical and chemical conditions of soils.
- An increase in the grouped area of permanent grassland, grasses and small-seeded legumes - 117%, constituting a fodder base for animals from the ruminant group.
- The remaining recognized crop classes, due to their smaller areas, are characterized by high variability. This variability is not always visible at the level of Poland, but is significant at the level of voivodeships. This requires further improvement in the process of identifying these crops.
- The decrease in the area of fruit tree plantations (52%) and fruit bush plantations (68%) results from methodological corrections made in comparison with previous years. Still, the recognized areas are not matching their size as expected.
- The area under strawberries remains to be verified – 281%. Preliminary findings indicate that it is mixed with fruit bushes, vegetables, charlock and several other crops. This will be verified in the September estimate, taking into account our methodology.

Chart 1. Area of crops in million hectares



a) An additional comparison was made of data on the area of crops in the Warmińsko–Mazurskie voivodeship.

Table 3. Sown area in the Warmińsko-Mazurskie voivodship

Cultivation	2020		2021	
	ARMA	Satellite Data	ARMA	Satellite Data
sugar beets	5 639	4 966	6 094	6 517
charlock	1 922	5 536	1 445	1 677
buckwheat	6 276	25 015	8 714	7 600
spring barley	22 548	28 190	24 468	20 041
winter barley	4 551	7 483	6 762	5 717
maize	82 030	76 261	87 692	90 769
cereal mixtures	21 378	22 576	21 461	26 316
oat	30 168	61 120	30 446	33 174
fruit tree plantations	1 276	41 250	1 613	15 809
fruit shrub plantations	1 502	27 231	1 751	19 804
millet	351	1 408	217	1 806
spring wheat	19 755	33 064	22 185	23 339
winter wheat	143 005	115 572	158 129	141 770
spring triticale	5 036	14 356	5 452	16 581
winter triticale	79 497	94 682	69 501	67 942
spring rape	2 408	17 212	2 484	3 922
winter rape	92 814	79 103	92 368	90 744
legumes	76 881	40 269	50 008	38 251
grasses and grasslands	572 199	410 603	435 895	435 326
strawberry	272	4 488	204	22 020
tobacco	22	262	19	85
vegetables	2 894	2 800	1 378	3 663
potatoes	4 778	2 829	5 868	4 135
herbs and spices	752	1 020	1684	686
rye	33 524	41 229	25 078	24 849
Total	**1 211 478**	**1 158 524**	**1 060 916**	**1 102 545**

The statement includes data from area applications submitted annually by farmers to ARMA. In 2021, after changes in the rules of their filling in, in the Warmińsko-Mazurskie voivodeship only 0.1% of the crop area was not marked (in Poland - 0.5%). Discrepancies between ARMA plot totals and plots obtained from Sentinel data may be due to:
- low spatial resolution of the Sentinel data, which results in the elimination of small plots;
- a very short time series of this year's reconnaissance - the data allowing for distinguishing the crops cover the period from mid-May to mid-July;
- possible errors in declarations by farmers - preliminary data before control of claims.

Conclusions

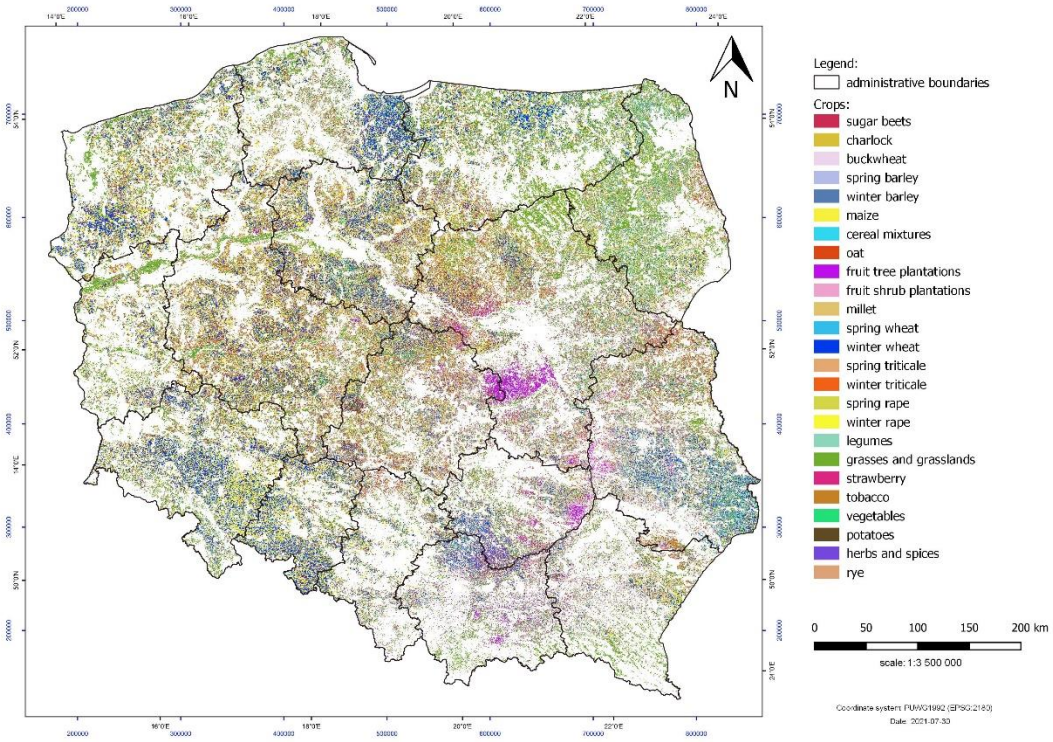
On the basis of the performed analyses, it is concluded that the time series of Sentinel-1 radar data covering the months of March-July is sufficient to obtain satisfactory accuracy in identifying winter crops and parts of cereals and spring crops. In order to obtain a proper estimate of the other crops that develop in later months (corn, beets, potatoes, tobacco, and others) it is necessary to extend the time series. The observation period should be extended to September, which would certainly improve the accuracy of crop classification. For small size plots, where the resolution of satellite data is insufficient, data from ARMA will be used.

The system of crop identification and monitoring using satellite data will be permanently implemented in statistical production from 2022 onwards, thus significantly reducing the conduct of surveys. The new system for obtaining data on agricultural crops, combined with the

possibility of wider use of crop data from ARMA, will form the basis of a new methodology for agricultural research. These changes will have a positive impact on the quality of the data and will greatly expand the presentation options.

The maps present the results of the preliminary estimate of agricultural and horticultural crops illustrated for the area of Polish (Map 1) and two selected communes from two different voivodships which varied in terms of the structure of the size of agricultural holdings i.e. the Wielkopolskie (Map 2) and Zachodniopomorskie (Map 3) voivodships.

Map 1: Preliminary estimate of the main agricultural and horticultural crops in 2021 based on remote sensing methods



The system of satellite identification of crops at the Statistics Poland allows for the recognition of classes of coverage of agricultural plots with a resolution of 100 m^2

The estimate of agricultural and horticultural crops for Polish developed on the basis of satellite images with a resolution of more than 100 m^2. The current use of images from satellites Sentinel type causes the elimination of small plots (usually less than 10 ares) and has a negative effect on the quality of the results. The solution to this problem will be estimates obtained from the satellite crop identification system using higher resolution images.

On the example of a selected commune in the Wielkopolskie voivodship, agriculture with a very diverse structure of crops and fragmentation of agricultural holdings was presented. This is an example of a municipality for which it can be expected to obtain results of estimates with a slightly larger error. For comparison, in the commune of the Zachodniopomorskie voivodship there are less types of crops and the areas of individual plots are much larger, which will relatively result in a higher level of their correct classification.

Map 2: Preliminary estimate of the main agricultural and horticultural crops in 2021 based on remote sensing methods the selected commune in the Wielkopolskie voivodship

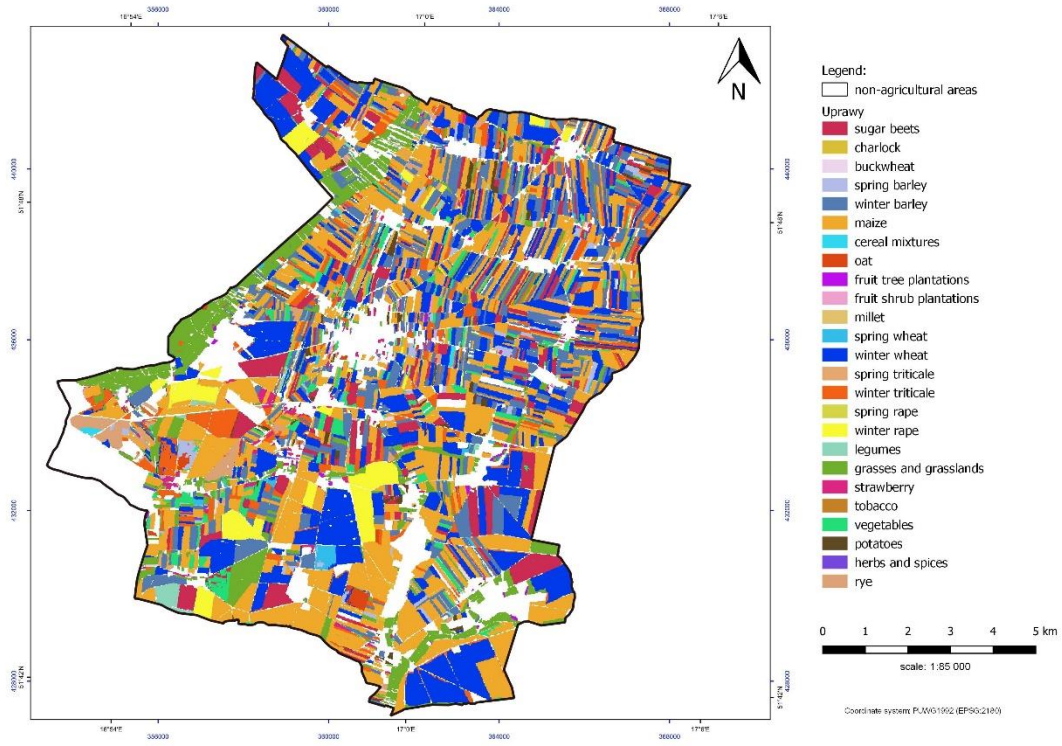


Table 4. Sown area in hectares in the selected commune in the Wielkopolskie voivodship

Cultivation	Area	Share
	in hectares	in %
sugar beets	799,66	7,35
charlock	3,61	0,03
buckwheat	19,32	0,18
spring barley	110,52	1,02
winter barley	1 424,77	13,10
corn	3 199,65	29,41
cereal mixtures	13,85	0,13
oat	63,59	0,58
fruit tree plantations	25,97	0,24
fruit shrub plantations	9,62	0,09
millet	0	0,00
spring wheat	50,22	0,46
winter wheat	2 180,53	20,04
spring triticale	27,42	0,25
winter triticale	720,6	6,62
spring rape	2,34	0,02
winter rape	337,46	3,10
legumes	75,72	0,70
grasses and grasslands	1 002,82	9,22
strawberry	111,13	1,02
tobacco	0,00	0,00
vegetables	358,56	3,30
potatoes	134,03	1,23
herbs and spices	21,45	0,20
rye	185,95	1,71
Total	**10 878,77**	**100,00**

Map 3: Preliminary estimate of the main agricultural and horticultural crops in 2021 based on remote sensing methods the selected commune in the Zachodniopomorskie voivodship

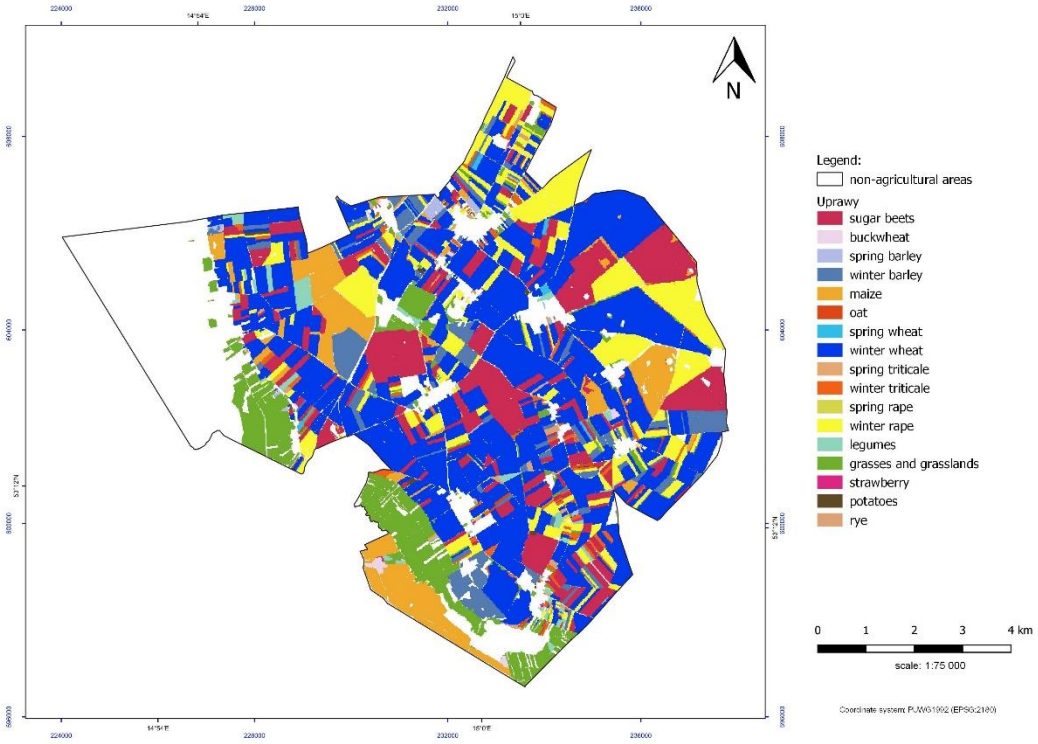


Table 4. Sown area in hectares in the selected commune in the Wielkopolskie voivodship

Cultivation	Area	Share
	in hectares	in %
sugar beets	1 099,02	15,88
buckwheat	20,81	0,30
spring barley	23,42	0,34
winter barley	421,31	6,09
maize	561,14	8,11
oat	13,39	0,19
spring wheat	16,15	0,23
winter wheat	2 968,19	42,90
spring triticale	5,83	0,08
winter triticale	140,41	2,03
spring rape	3,09	0,04
winter rape	868,65	12,55
legumes	101,88	1,47
grasses and grasslands	624,65	9,03
strawberry	4,56	0,07
potatoes	15,28	0,22
rye	31,36	0,45
Total	**6 919,14**	**100,00**

Substantive study
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Related studies

Results of the application of satellite remote sensing methods for the development of a preliminary estimate of the main agricultural and horticultural crops

Land use and sown area in 2019

Production of agricultural and horticultural crops in 2019

Subject available in databases

BDL: Sown area

Main terms available in the dictionary

Sown area