The use of satellite pictures and data provided by drones for the purposes of identification of crops and assessment of plant production

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ABSTRACT

The first part of the speech will present the results of cooperation between the Department of Agriculture in the Central Statistical Office and the Space Research Centre of the Polish Academy of Sciences in Warsaw. It will be concerned with the possibility of distinguishing particular groups of crops and classes of land cover, including identification of selected crops on the basis of satellite images (taken by Sentinel 1 type satellite) to the lowest possible level of aggregation, i.e. voivodship (NTS2) or district (NTS3). Such research was conducted on a selected Polish voivodeship in 2015. The speech will present the applied method of sample selection (ca. 550 measurement plots) based on administrative sources of the IACS, the field survey of crops in that area, the adopted methodology of identification of crop groups, as well as the possibilities to use data from Sentinel 2 type satellite for such kind of work.

The second part of the speech will present a study of the data acquired from a drone approach for the purposes of assessment of production from grasslands. The work was developed in cooperation with the Department of Agriculture in the Central Statistical Office and the Institute of Geodesy and Cartography in Warsaw in 2015. The analysis was conducted on 21 plots with total area of approximately 460 ha of permanent grasslands in the selected voivodships. It is planned to describe the methodology of the research consisting in using non-piloted measuring platform (a drone) equipped with a hyperspectral camera capable of imaging within the scope of 480-890 nanometres. Imaging with the use of a drone took place in the course of two field campaigns conducted at the turn of May and June of 2015, and was supplemented with data from LANDSAT 8 satellite in the case of fragments of plots, for which obtaining data with a drone was impossible due to adverse weather conditions. Additionally, simultaneously with the conducted drone approaches, ground measurements were conducted (74 points within the area of the analysed plots), using specialist apparatus owned by the Institute of Geodesy and Cartography, providing information about LAI (Leaf Area Index), soil humidity and temperature of plant surface. The collected data described above enabled analysing and assessing production on grasslands by assigning to each indicated plot the estimated value of fresh biomass and biomass per hectare. A starting point for such an analysis was a comprehensive set of data, collected within a few decades by the Institute of Geodesy and Cartography, enabling the use of already created, and used by the Institute for many years, models describing the correlation between biomass and the LAI. The collected information about the crop yield from grasslands were compared with the local estimates of experts. During the

speech, it is planned to present chapters describing one by one the specification of data and sensors used to obtain them, the applied methodology of assessment of production size from the designated grasslands, the results of the conducted analysis with breakdown into particular plot groups. A SWAT analysis will be also presented, summing-up the conducted research and assessing the potential of the used method.

Keywords: Drone, IACS, Sentinel, Grasslands

1. Introduction

1.1 Preface

The Agriculture Department at the Central Statistical Office OF Poland (CSO) is responsible for maintaining official national statistics connected with agriculture in Poland. Its standard work based on annual periodic surveys, information obtained from field experts, voivodship experts, and administrative data, includes the processing of information on issues such as area assessment, yields, and crops at the voivodship level (NTS2). There is a demand for data pertaining to aggregation at the district (NTS4) or commune (NTS5) levels. Unfortunately, the information that has been collected to date during questionnaire surveys is based on farmers' declarations as regards the land used, but without details on the locations of such land. This makes it impossible to aggregate results at a level which in terms of area is classified lower than voivodship. Therefore, new methods, possibilities and solutions are sought for in order to increase the accuracy of estimates. The Agriculture Department is closely following the latest technological developments and possibilities of applying them for its own needs, in particular the Copernicus programme and missions by the Sentinel satellites. The satellites of this type are developed under the Copernicus programme, funded by the European Commission and the European Space Agency (ESA). It should be noted that while being free of charge, the efficient use of data transmitted by these satellites requires substantial experience and knowledge on remote sensing. For this reason, close cooperation with a number of institutions is being conducted, allowing these data to be used directly.
The report consists of two thematic blocks presenting the results of cooperation between the CSO and scientific institutions in order to improve the quality of published data and enhance their usefulness by increasing the resolution of presented data.

1.2 Part I

The first part of the report presents the results of cooperation between the CSO, the Regional Statistical Office in Olsztyn (RSO), and the Space Research Centre of the Polish Academy of Sciences (SRC) within a pilot study in one of the voivodships, aimed at assessing whether it would be possible to single out and identify individual crop groups on the basis of radar data from the Sentinel 1 satellite and field calibration based on data from the Agency for Restructuring and Modernisation of Agriculture (ARMA) – the database of the Land Parcel Identification System (LPIS).

1.3 Part II

The second part of the report discusses the results and experience gained in the implementation of a contract between the CSO and the Institute of Geodesy and Cartography in Warsaw (IGiK). The contract regarded the preparation of a study on the possibility of assessing grassland production on the basis of image information transmitted with the use of an unmanned measurement platform (a drone) and a hyperspectral camera.

2. Part I

2.1 The objective of the study

As part of the study, crops in the Warmia and Mazury voivodship were identified with the use of Sentinel-1 satellite radar images. The images served the creation of a data time series presenting how the crops evolved throughout 2015, and then were processed and classified. As reference data, the administrative databases on crops, including data from the LPIS database were utilised. The results were aggregated at the district and voivodship levels.

2.2 The methodology for selecting samples and conducting in situ survey.

The Warmia and Mazury voivodship is located in the north-eastern corner of Poland. To select a random sample, the coordinates of points from the European LUCAS 2012 survey were used. First, an analysis was carried out to designate points potentially located on agricultural areas. With the use of ArcGIS software (the Intersect function), the LUCAS 2012 points were analysed in relation to the vector layer of managed land (ML) from ARMA. As a result of the analysis, 885 points were selected on record parcels with the area of nearly 213 km^2.

Figure 1: *A sample point selected for the analysis*

In order to increase the likelihood of selecting points that were located within large-area crops, 885 points were additionally analysed in relation to the record parcel layer. As a result of this analysis, the designated points were grouped in line with the adopted field size buffers. Each interviewer had to visit all points assigned to him/her and collect the necessary data, as specified in the form for the in situ survey. The interviewers were provided with GPS receivers with navigation capabilities in order to arrive in a given point and record its actual location, as well as GPS-capable tablets to take geotagged photographs. For each analysed point, a description had to be prepared in accordance with a questionnaire drawn up earlier. The collected data regarded issues such as the type of crop – a dropdown list of plants, with the possibility of providing more details on a given species, the homogeneity of a crop, the plant development stage, land topography, the type and humidity of soil, the amount of weeds, and the angle in which a photograph was taken in relation to the cardinal directions. In total, the interviewers provided descriptions for 596 points and took 1847 photographs. The field studies were held between 15 June 2015 and 22 July 2015.

2.3 Reference data

Satellite data were classified on the basis of information from the database on crops in the Warmia and Mazury voivodship in 2015. The database contained geospatial information on control areas, crops cultivated on them, the interviewer's location, a survey on the state of a crop and a field, and photo documentation. The report was made on the basis of type-2 data registered in the VH and VV polarisations. Since the beginning of 2015, more than 300 Sentinel-1 capturing the area of this voivodship. The data were collected automatically and for further analyses, 13 scenes were selected.

2.4 Data processing

The multitemporal coherence matrices for satellite radar images were calculated with the MT_SAR software developed specifically for this purpose by the SRC. With the software, multitemporal polarimetric processing can be performed, including correlation and coherence matrices serving as a basis for applying polarimetric decompositions that model the mechanisms of reflection of radar beams from structures on the surface of the Earth. The software can also automatically process large image sets. In order to speed up the calculations and for safety reasons (minimising the risk of interruption of prolonged calculations), the images were divided into smaller pieces.

Figure 2: *Contour of the voivodship (in green) with a mosaic of cut-up pieces*

For each of pieces, calculations were carried out with regard to the coherence matrix, entropy, and the polametric Alpha parameter. Upon completion of the calculations, the pieces were merged together. By means of the functions offered by the Sentinel-1 Toolbox, each of the 13 images selected with the Wishard's classifier was subjected to polametric unsupervised classification. The methods of supervised classification were deployed on the basis of training fields defined by means of the information on crops obtained by CSO interviewers for statistically selected plots within the analysed voivodship. Segments were created with the use of optical data from the Landsat 8 satellite and LPIS vector data provided by the ordering party. With LIPS taken as reference, the first level of segmentation was developed, overlapping borders of the LPIS plots. The segments thus obtained were used in the next step of the segmentation process, where the plot-designation plots were divided depending on the value of Landsat spectral images, in such a manner as to ensure that the newly created segments reflected the structure of sown areas.

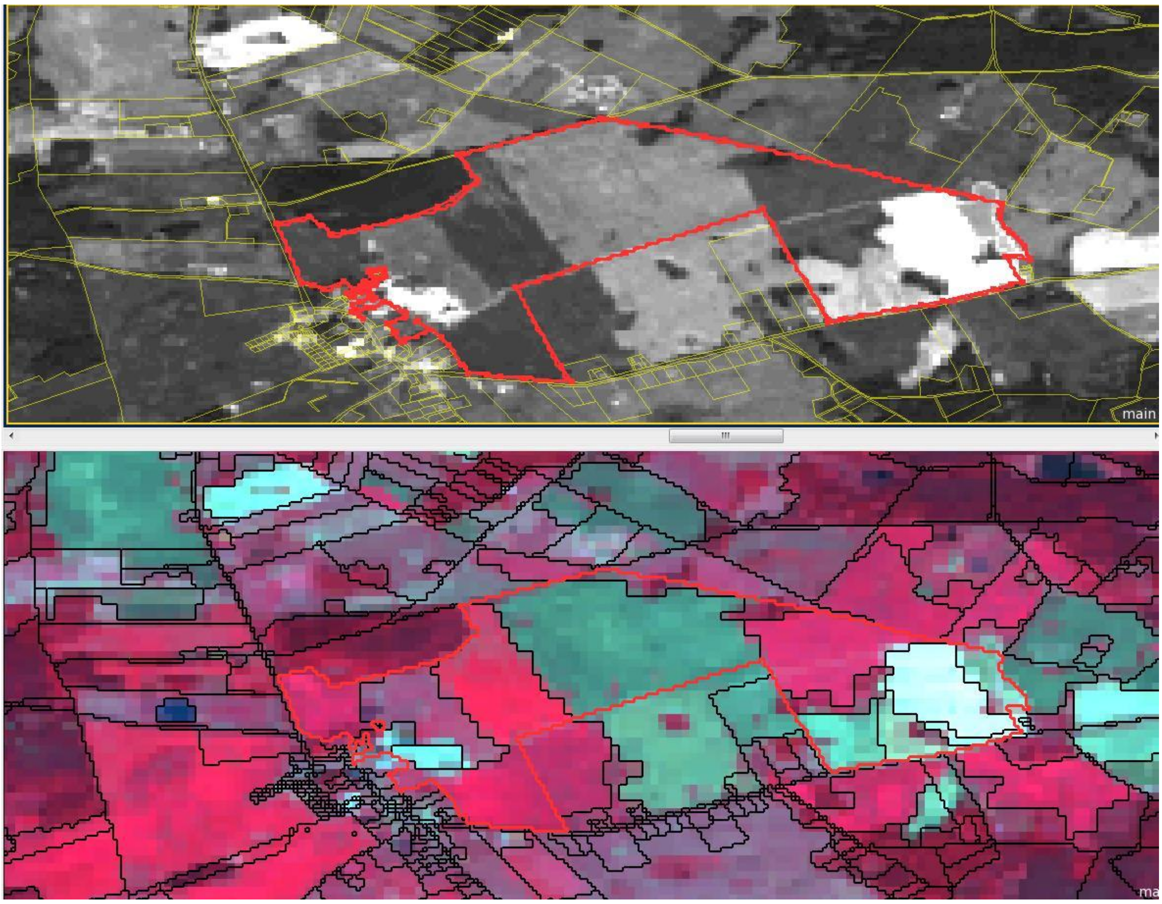

Figure 3: *Updating the borders of arable fields. Top – plot borders determined on the basis of the LPIS database; bottom – new crop borders obtained on the basis of segmentation of a multispectral Landsat image.*

2.5 Results of the classification

Three different classification algorithms were followed: Decision Trees, K-Nearest Neighbours and Support Vector Machine. The accuracy of the obtained results of classification was assessed on the basis of training fields and also with the use of an independent set of data from farmers' questionnaires collected in the ARMA system. The most reliable results were obtained for the classification carried out on the basis of Wishard's distance parameters, with the K-Nearest Neighbours method (KNN) and with the use of the temporal series of the σ0 back-reflection coefficient with the Support Vector Machine (SVM) method. To continue the assessment of the classification results, the areas of crops obtained through the classification of Sentinel-1 radar images and the estimated sown areas recorded in the CSO system were compared. Next, the results of crops were aggregated at the district level.

2.6 Summary and conclusions

Each classification of satellite images should conclude with an assessment of the results, to provide a basis for establishing the usability of image processing methods. In this case, the classification was assessed by being compared with the official CSO data on the status of crops in the Warmia and Mazury voivodship in 2015. At the same time it should be noted that, given the limited number of validation points, the results of the validation are indicative only.
The conclusions:

- The random selection of training fields should be replaced with the supervised method which allows selecting the sufficient number of large, adequately shaped fields that are well representative of each crop.
- The training fields should be identified at the level of the LPIS database, not on the basis of GPS indications during field measurements.
- Each point should be verified on the basis of photographs taken during a visit on the field.
- The validation on independent data were subjected suggests that the method has considerable potential, it also indicates the need for seeking other solutions, e.g. supplementing the data with optical photographs.
- The results of object classification depend on the quality of segmentation.
- The analyses of multitemporal radar data are connected with the necessity of processing very large image sets. All stages of classification work must be optimised in terms of the duration of operation and calculation capabilities.

3. Part II

3.1 The objective of the study

As part of the work we attempt to use drone with a hyperspectral camera for the purpose of estimating the production of permanent grassland.

3.2 Characteristics of the study area and used equipment.

The analysis covered the area of 21 plots indicated by the CSO, with total area of 460.2 hectare, located in the area of the Biebrza National Park (the BPN). During implementation of the project, to obtain hyperspectral imaging from low altitude an unmanned measurement platform (drone) was used in the form of multicopter with six rotor. Multicopter VersaX6 with take-off mass of 4 kg is able to carry measurement apparatus with weight up to 1.5 kg. The system of autonomous flight handling integrated in the platform allows conducting ortophotogrammetric flights in semi-automatic mode, when the platform follows the route of flight scheduled before along with possibility to set points of hovering optimising acquisition of data from hyperspectral camera. Total of 19 flights was performed along the routes programmed on the basis of cartographic materials prepared before and land survey. The distance of single flight was within the range of 1,000 – 2,000 meters and was performed at the altitude of 150 or 200 meters. To obtain hyperspectral imaging the Rikola full frame camera was used, imaging within the range of 480-890 nanometers. During flight imaging was performed in 16 spectral channels.

3.3 The survey methodology

Imaging from drone took place in the course of two field campaigns conducted on May and June 2015. For the needs of the project, fragments of two scenes coming from Landsat 8 satellite were used. In addition, simultaneously with conducted flights the ground measurements were performed (74 points on the area of the analysed plots) using specialist apparatus being in the possession of the Institute of Geodesy and Cartography, offering information about LAI (Leaf Area Index, ratio of projection area of leaves), humidity of soil and temperature of plants' surface. The collected data described above allowed for analysis and calculation of the production from the grasslands by assigning to each indicated plot an estimated value of fresh biomass and biomass with regard to one hectare. The main and the most time-consuming stage of the analysis was to prepare adequately the imagery acquired from the drone. Those images were then calibrated and combined to create a single mosaic for each of flights. The next step was establishment of colour composition (in false colours) and calculation of normalised difference vegetation index - NDVI, used in further parts of analyses.

Together with values from range (-1, 1) we obtained information on the development state and condition of vegetation, and high values of index correspond to the areas overgrown with thick vegetation of good condition. Based on the dedicated models, calculated values of fresh biomass from hectare were assigned to homogenous areas of the analysed fields and after calculation of surface of those areas a total estimated weights were obtained of fresh biomass (in tons) and of biomass from hectare (in tons/hectare), separately for each of the analysed plots.

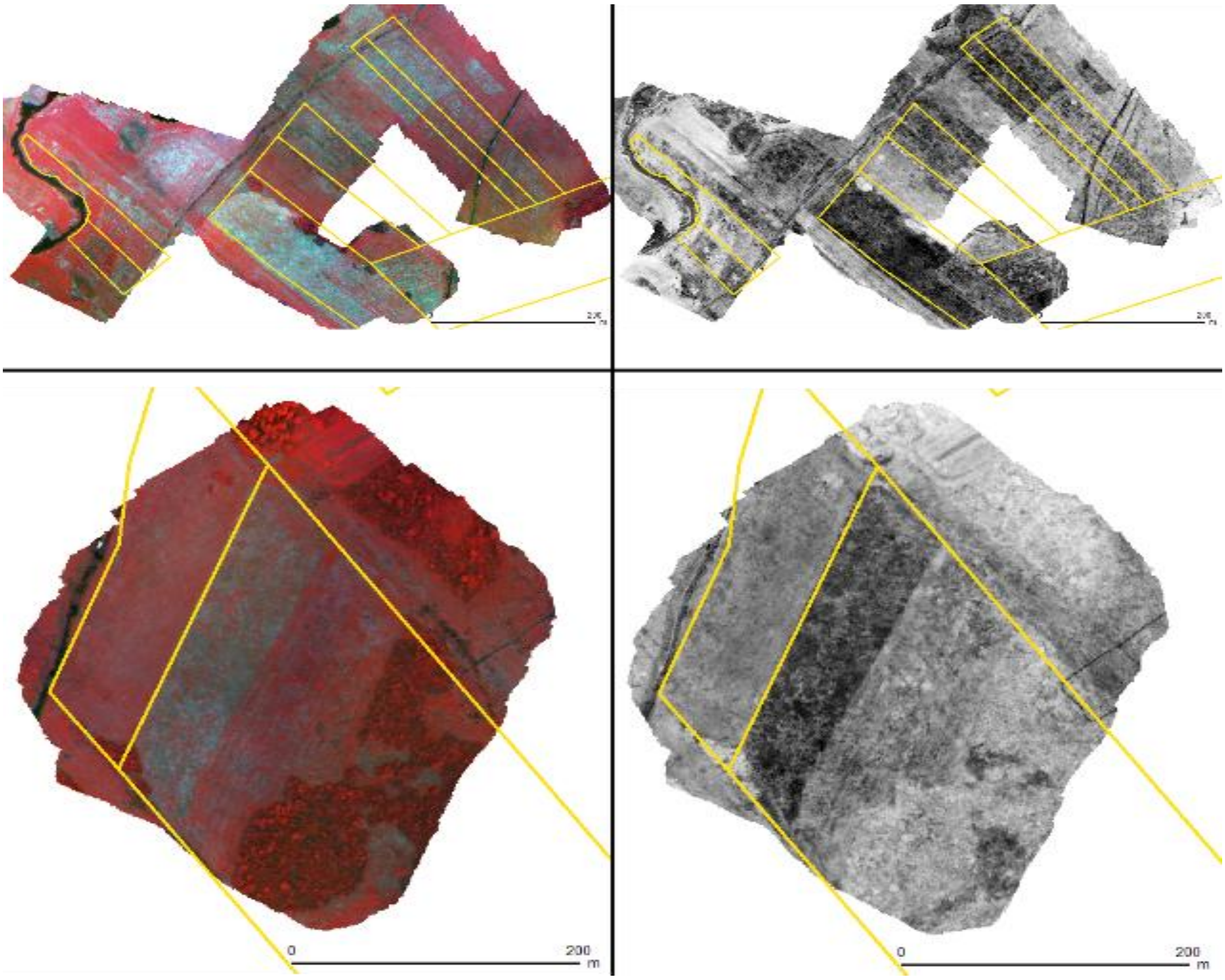

Figure 5: *Two examples of data obtained from drone; on the left, the composition of channels 16-6-4 (bluish areas correspond to sections of meadows with larger share of dry vegetation) on the right established NDVIs.*

3.4 Evaluation of accuracy and summary

To summarise this project, it is worth paying attention to pros and cons of the decision on using this technology to obtain teledetection data, so that it could be used intentionally and reasonably for subsequent analyses. An unquestionable advantage of imaging with the use of a drone is the possibility of taking pictures at low heights, as low as a few dozen meters, as well as smooth selection of height in vertical profile (which is impossible in the case of an aircraft or a satellite). Thus, such pictures are characterised by high spatial resolution, impossible to obtain by satellite images. Spatial resolution at the flight ceiling of 200 m. is approx. 12 cm. Such level of detail is necessary for precise determination of models, as well as for modification (detailing) of mathematical models used for image analyses, e.g. satellite images with greater data generalization, covering significantly larger areas. Obtaining such detailed images for large surfaces, e.g. community area, would be excessive. Therefore, for such areas, imaging is made at higher ceilings (at the same time, the image covers a significantly larger area). Important factors include also mobility, flexibility and relatively small cost of conduct of a single flight that can be carried out with a possibly short preparation time. Additionally, the need to maintain eye contact with the device by the drone operator provides a chance for good recognition of the imaged areas from the ground level and execution of additional measurements, which positively affects the accuracy of analyses.

On the other hand, the use of a drone has clear limitations that were impossible to avoid also in the case of the concerned project. The time of a single flight amounting to ca. fifteen minutes, high dependence on weather conditions, fairly low threshold conditions for wind power, during which flights cannot be performed for safety reasons (but also due to image quality), as well as the need to maintain eye contact with the drone limiting the scope of the survey - those factors result in the fact that the use of a drone in the case of analyses of large surfaces becomes difficult and ineffective.

But stronger winds means that even when using advanced stabilization, the individual channels can be spatially offset in relation to each other, which raises the need to use the compilation of time-consuming algorithms automatically adjust to each channel, or very time-consuming - even manual geometry corrections. This need not occur when we could use the muli-lens camera recording the appropriate channels at the same time (which of course increases the weight of the camera).

Trying to simulate the performance of imagery from drone on a scale of Podlaskie province with an area of 20180 km^2, where being a potential interest to agricultural land is 10741 km^2 (CSO, 2013) and based on framework price list of one of the companies carrying out flights by drones, total, multimillion cost and the huge amount of time needed for the execution of such a large area of the project make use of established technology, it is impossible to predict.

3.4 Recommendations

With the analysis of agricultural production with the use of remote sensing techniques, the first step should be to align the source of the obtained data for the planned scale of the study and the needs related to spatial resolution. While in the case of single plots, imaging from the level of a drone can provide valuable material for the purpose of conducting detailed analysis of production from grasslands, as well as provide possible additional significant data for verification of models used for analysis of image content. In the case of municipality or district levels, it may be more reasonable to use data from small airplane flights, with the use of the same equipment as the one used in drone studies, or even data from satellite (e.g. data from satellites Landsat 8 or Sentinel-2), which may enable analysis in the scale of a voivodeship, districts or the whole country.