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COMPARISON OF TWO REMOTE NITROGEN UP-TAKE SENSING METHODS TO DETERMINE NEEDS OF NITROGEN APPLICATION

Summary

Precise (depending on the planting demands, varied season-season, field to field, and even site to site) nitrogen fertilization is the way enabling the costs minimizing of application, the lower nitrogen balance in soil and the groundwater protection process as well as maximizing the yield. Comparison of two remote sensing methods of plants' nitrogen needs during vegetation season has been conducted. Measurement with Yara N-Sensor facilities installed on tractor's roof and multispectral camera (Parrot Sequoia, R, G, RED and NIR bands) installed on UAV has been taken.
***Key words**: organic farming, sustainable farming, nitrogen sensors, multispectral camera, plant health indices, NDVI, UAV, drone*

PORÓWNANIE DWÓCH ZDALNYCH METOD POMIARU POBRANIA AZOTU PRZEZ ROŚLINY W CELU WYZNACZENIA POTRZEB NAWOŻENIA AZOTOWEGO

Streszczenie

Precyzyjne (zależne od zapotrzebowania roślin, zmienne względem sezonu, pól czy nawet stref pól) aplikowanie nawozów organicznych jest sposobem do zminimalizowania kosztów aplikacji i zrównoważenia bilansu azotowego w glebie i zapobiegania wymywaniu azotu do wód gruntowych oraz do maksymalizacji plonów. Przeprowadzono porównanie dwóch metod zdalnego pomiaru zapotrzebowania roślin na azot w czasie wegetacji. Wykonano pomiar pobrania azotu przez uprawę rzepaku ozimego za pomocą urządzeń Yara N-Sensor (czujnik optyczny zamontowany na dachu ciągnika rolniczego) oraz kamery multispektralnej (Parrot Sequoia, pasma R, G, RED, NIR) podwieszonej do pojazdu bezzałogowego (BSL). Pomiar przeprowadzono w listopadzie i grudniu 2016 roku.
***Słowa kluczowe**: czujniki pobrania azotu, kamery multispektralne, wskaźniki zdrowotności roślin, normalizowany różnicowy wskaźnik wegetacji, NDVI, bezzałogowe statki latające (BLS), dron*

1. Introduction

Nitrogen, as main factor of plants growth and health is crucial to achieve high crops both in intensive and ecological (sustainable) agriculture. The fact of nitrogen spatial variability inside field is commonly known and researched. It depends on soil category, soil texture, terrain configuration, rainfalls, nitrogenization of canopy plants rest and amount of available nitrogen. Chemical fertilizers and natural fertilizers (manure, slurry) are very rich source of fast available nitrogen and other valuable macro elements and micro elements. In agriculture, particularly in sustainable farming, exact application is essential for yield and economic optimization. Moreover, having no correct information about nitrogen accumulation in soil, there is possibility of over-application- causing crop lost (lodging or over-density of canopy) and washout nutrients to groundwater.

The basis of variable application of fertilizer is information-accurate map of spatial availability in soil needs of nitrogen. Nitrogen availability of soil tests method did not evaluated much since beginnings of precision farming. Taking soil sampling, from three or two depths (30-60-90), GPS assisted, and laboratory tests are procedure up to today [2, 3]. Unfortunately, it causes many problems (long time between taking samples and results, technical issues of taking sampling in late winter, spatial density, nitrogen nature to evaporate, high costs, etc). Moreover, with future possibilities of top-dressing application of fertilizer, rate splitting during vegetation season basing on current demand of plants is possible. In such case application of nitrogen can be splatted to two or three rates, avoiding problem with calculation of accurate supply and demand values in case of different season-to-season and field-to-field differences. For such fertilizing techniques, soil sampling and nitrogen testing is unsuited.

Plants' nitrogen uptake and current demands (nitrogen uptake and nitrogen demands are used in this article interchangeably, with relation of both indicators: *nitrogen application = demands-uptake*) can be measured with remote sensing technologies. Many researches have been carried out for cereals based on leaf colors measurement and biomass [4, 5, 6]. In winter rape having nature to enlarge its leaf area as result of nitrogen up taking, biomass measurement and correlation to up-take of nitrogen has been developed. As remote equivalent of standard methodology (cutting off and weighing leaves from 1 square meter of field [3]), special methods are developed and few market ready solution are available [7, 8, 9].

One of these is N-Sensor from Yara corporation [10], with two band measurement heads. The principles of measurement with these sensors were researched by Wojtowicz at all [8].Two receiver heads are installed on both sides of the main unit. Two-band sensors measure plants' reflectance of light produced by itself. Sample of solution is shown in Fig. 1. In this way, measurements are independent of ambient, changing light and can work 24 hours/day. It works together with dedicated software, where measured values of biomass can be seen on-the-go and recorded with coordinates from supplied DGPS receiver. One of the constrains of system is only 1/3 or 1/4 of working path measurement (about 3 meters on both sides of tractor) which may cause serious errors in sensing, especially close to field borders and corners. Result of measurements are displayed in non-unit values from 0 (no biomass) to about 15 (high biomass, maximal value observed by authors). Starting from 2013, software visualizes nitrogen up-take map in kg/ha, produced from simple multiplying biomass index by 100. Other, newest solution is multispectral camera from Parrot company, Sequoia, with 4 narrow light wave bands plus RGB camera for UAV solution [11]. Drone with mounted multispectral camera - Parrot Sequoia is shown in the Fig. 2. Remote sensing with single band cameras, RGB and multispectral are widely researched and developed. Principles of multispectral plant health measurements have been described by Mazur and Chojnacki [12]. By capturing pictures in individual bands, with proper overlap and height over the plants, with the use of dedicated software, orthofotomap is being generated. The comparison of the technical parameters of of Yara N-Sensor ALS system and Parrot Sequoia multispectral camera is shown in Tab. 1.

Different indicators have been developed to detect plant health. Normalized Differential Vegetation Index, which is described by mathematical formula (1) is the most popular and easy to interpret.

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)} \quad (1)$$

Where NIR is near infrared band value and RED is the band value. NDVI indices vary in range of -1 (no plants) to 1 (full plant coverage) and can be used in determining needs of nitrogen application.

The purpose of this study was to compare two systems for determining nitrogen requirements by plants: Yara N-Sensor ALS system and multispectral camera installed on drone.

2. Materials and methods

Comparison has been conducted between both methods on winter rape field. Measurements has been taken in November/December of 2016 on field close to Stargard - Sułkowo. (North-West Poland). Data from Yara N-Sensor have been collected (log file with biomass index values with GPS coordinates) and converted to vector map (ESRI SHP), and contour map has been created after interpolation using Arc Map Software.

Multispectral measurements have been conducted with Parrot Sequoia camera with GPS module installed on AGRODRON® XL multirotor UAV and two autonomous mission flights on 300 meters AGL have been projected and flown to cover field area with proper overlap (80%) - 3600 pictures have been collected and processed in Pix4D software, as final results having NDVI indices map with 12cm/pix resolution as GeoTiff file (file size about 1,2 GB). Flight path of the drone with multispectral camera and the shooting points of photographs are shown in Fig. 3.

Source: own work / Źródło: opracowanie własne

Fig. 1. Yara N-Sensor ALS during work
Rys. 1. Yara N-Sensor ALS podczas pracy

Source: own work / Źródło: opracowanie własne

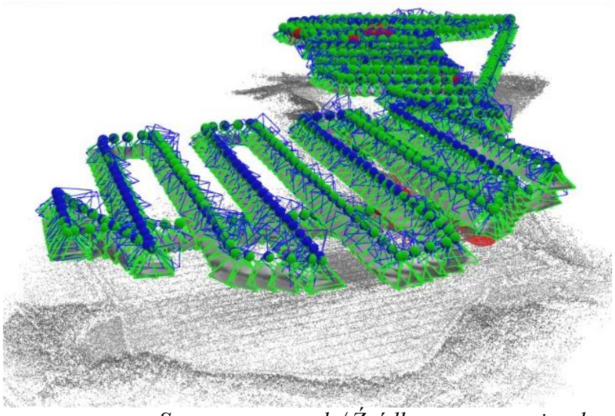
Fig. 2. Parrot Sequoia multispectral camera installed on Unmanned Aerial Vehicle (UAV)
Rys. 2. Kamera multispektralna Parrot Sequoia zainstalowana na bezzałogowym statku latającym (BSL)

Table 1. Technical parameters comparison of Yara N-Sensor ALS system and Parrot Sequoia multispectral camera
Tab. 1. Porównanie parametrów technicznych systemu Yara N-Sensor ALS i kamery multispektralnej Parrot Seqouia

	Area coverage [%]	Bands	Measurement		
			spatial resolution	frequency	distance
Yara N-Sensor ALS	20-30 (depends on tramlines widths)	2 (band width and frequency not known)	36m x 3,3 m spots*	1/1 second	About 3 m above the plant
Parrot Sequoia	100	Red - 660 nm, 40 nm bw, Green -550 nm, 40 nm bw, Red Edge -735 nm, 10 nm bw, Near Infrared -790 nm, 40 nm bw	0,12x 0,12 spots**	n/a	About 300 m above the plant

* Spot area calculated for 36 meters tramlines width and speed of tractor 12 km/ha
** Spot area for UAV flight heights 300 meters above ground level

Source: own work / Źródło: opracowanie własne



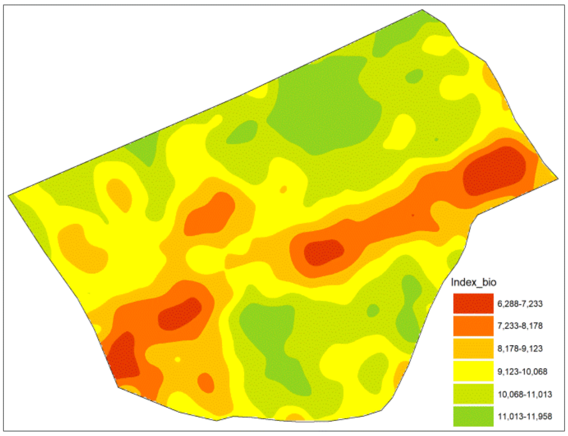
Source: own work / Źródło: opracowanie własne

Fig. 3. Flight path of UAV and points of multispectral photos during mission under the field, prepared in Pix4DAG software

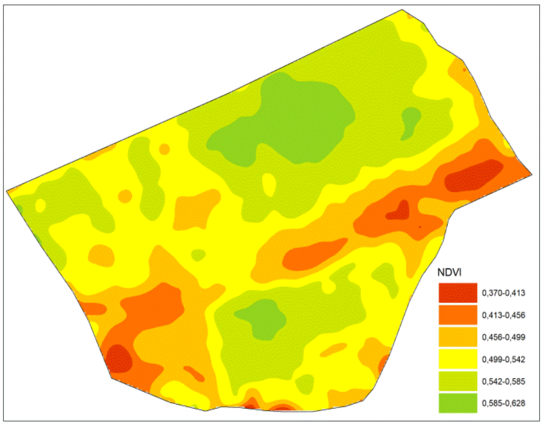
Rys. 3. Tor lotu drona i punkty wykonania zdjęć multispektralnych przedstawione za pomocą oprogramowania Pix4DAG

The map with biomass index of field is shown in Fig. 4A. The map of the same field with NDVI indices is presented in Fig. 4B. In both result map trails point with low leaf coverage have been removed as erroneous.

A



B



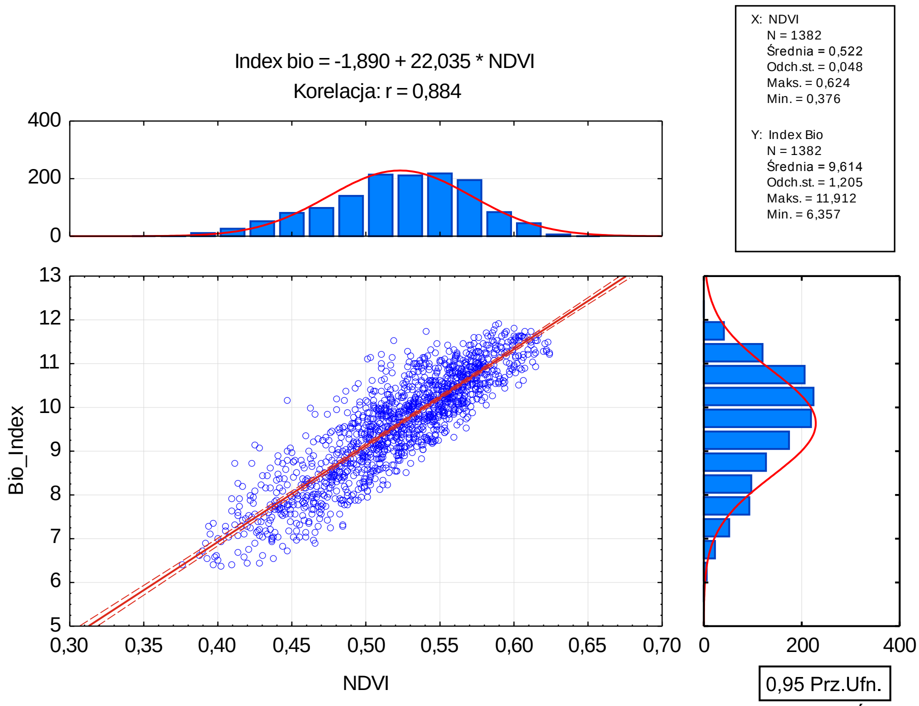
Source: own work / Źródło: opracowanie własne

Fig. 4A. Biomass index values map of field in Sułkowo (postprocessed)

Rys. 4A. Mapa wartości wskaźnika biomasy na polu w Sułkowie (dane przetworzone)

Fig. 4B. NDVI indices values map of field in Sułkowo (postprocessed)

Rys. 4B. Mapa wartości wskaźnika NDVI na polu w Sułkowie (dane przetworzone)



Source: own work / Źródło: opracowanie własne

Fig. 5. Regression equation and correlation coefficient for biomass index and NDVI values

Rys. 5. Równanie regresji i współczynnik korelacji dla wartości: wskaźnika biomasy i NDVI

3. Conclusions

In spite of differences in way of measurement and those in needed equipment, both methods (using Yara N-Sensor and multispectral camera with drone) in assessing the demand for nitrogen for crops are comparable in identifying and designating.

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