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REMOTE GRASSLANDS CROP PRODUCTIVITY MEASUREMENTS WITH USAGE OF MULTISPECTRAL CAMERA AND SMALL UNMANNED AERIAL VEHICLE

Summary

Grasslands, with about 40% coverage of entire Earth's surface as a source of valuable animal food in situation of still increasing cost of production are in need of special care concerning its performance, conservation and productivity. In times of intensive production and decreasing arable areas and increasing costs of animal production, diversified and quality management is required for grasslands. Highly developed precision farming tools, commonly used in cereals crops, especially remote sensing, allowing nondestructive, fast and accurate monitoring during grow season, can be adopted to grasslands in the framework of organic animal husbandry as well. Aim of this article was attempt to check remote sensing of grassland biomass as precision, high-performance and low-cost substitute of currently developed method with use of handheld biomass meter-herbometer. Research has shown that there is possibility to find mathematical relationship between the NDVI values and the grass height in the pasture.
***Key words**: organic farming, sustainable farming, remote sensing, precision agriculture, multispectral camera, UAV, plant health indices, NDVI.*

ZDALNY MONITORING WYDAJNOŚCI PRODUKCYJNEJ PASTWISK ZA POMOCĄ KAMERY WIELOKANAŁOWEJ I MAŁEGO BEZZAŁOGOWEGO STATKU POWIETRZNEGO

Streszczenie

Pastwiska, stanowiące około 40% pokrycia Ziemi jako źródło wartościowej paszy dla zwierząt hodowlanych w sytuacji rosnących kosztów produkcji wymagają szczególnej uwagi odnośnie ich wydajności i jakości. W obliczu intensywnej produkcji zwierzęcej, zmniejszaniu powierzchni upraw i rosnących kosztów, pastwiska wymagają poszerzonego i wysokiej jakości zarządzania. Wysoce rozwinięte narzędzia rolnictwa precyzyjnego, powszechnie stosowane w uprawach zbożowych, a szczególnie zdalna detekcja, umożliwiająca bezinwazyjny, szybki i dokładny monitoring w czasie sezonu wegetacyjnego, mogą być również zaadaptowane do pastwisk w ramach ekologicznego chowu zwierząt. Celem artykułu była próba sprawdzenia metody teledetekcji biomasy łąkowej jako precyzyjnego, wysokowydajnego i taniego zamiennika obecnie stosowanego sposobu do pomiaru biomasy łąkowej z wykorzystaniem ręcznego herbometru. Badania wykazały, że istnieje możliwość znalezienia zależności matematycznej między wartościami współczynnika NDVI a wysokością trawy na pastwisku.
***Słowa kluczowe**: rolnictwo ekologiczne, rolnictwo zrównoważone, zdalny pomiar, rolnictwo precyzyjne, kamera wielokanałowa, BSP, wskaźniki wigoru roślin, NDVI.*

1. Introduction

In accordance with the requirements of organic farming, in the pasture season, animals should have access to pastures. Pastures, particularly grasslands, are important element in organic farming because they provide the cheapest and full-value feed, which can be the only feed for cattle in summer. The condition of grasslands and the quality of a forage produced on them affect the condition and health of animals, their behavior and also the quality of animal products [4].

For a farmer, animal production in organic farming is not only care of animal welfare, it is also an economic activity that should bring a profit. Economical rules require responsible managing to make best profit from given area. To make right decision, access to substantial information is required: up-to-date, accurate and understandable site and time-over-the-season specific information about soil (moisture, temperature) and plants (health, drought stress, yield potential).

Since development of global positioning system (GPS, Navstar) and remote sensors for soil and plants scanners in early nineties, site specific measurements as part of Precision Farming practices are available for common crops as wheat, corn, oil seed rape and others. Observation of leaf area in specified bandwidth, can give information about plants condition:

Recent development of compact size and light wave multispectral cameras carried by small unmanned aerial vehicles (UAV) with appropriate data processing software, both desktop and web based, allow seasonal plants' monitoring on large area. A lot of usable spectral indices have been developed, with most popular Normalized Difference Vegetation Index, described by mathematical formula:

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

where:
NDVI - Difference Vegetation Index,
RED - reflectance in red range, (668-683 nm),
NIR - reflectance in the near infrared range, (898-913 nm).

Such information can be very useful for determining zones of unhealthy plants, low biomass or other plants abnormal stadiums.

Precision farming practice, successfully evaluated in arable farming, also in organic farming, is being started to be introduced in pasture. In combination with drones for observing vegetation in pastures, advanced technologies for animal observation and identification may be used. The Dogg Bone Drone remote monitoring technology from Herd Dogg consists in collecting data from tags mounted on animals via the drone [9]. The use of unmanned aerial vehicles to identify animals in the pasture with the possibility of assessing the state of vegetation in the pasture will allow the creation of new herd management techniques in organic farming.

The use of multi spectral analysis and drone for the assessment of the condition of plants in fields and pastures is difficult both in data acquisition and in their interpretation. Schellberg et al. in their research found that, among other precision farming tools developed for grasslands as heterogeneity management, digital image analysis (DIA) of near-ground imagery and yield measurement systems, remote sensing for precision pasture and livestock management is very interesting and prospective [7]. They suggest that key to successful precision agriculture rather than collecting data is their understanding and interpretation, seeing more rapid development of PA in grassland when adequate sensors for rapid non-destructive measurement will be available. Von Bueren et al. tested four different UAV-carried optical sensors over grassland: standard RGB camera (Sony Nex5n), DYI IR compact camera (Canon PowerShot), multispectral camera (Tetracam MCA6) and spectrometer (UAV STS) comparing them with ground meter ASD HandHeld 2 [8]. All tested sensors correlated well, especially professional grade (Tetracam, STS) with suggestion of high caution concerning customer grade camera, especially being used for quantitative vegetation monitoring. Von Bueren found radiometric calibration of measurements as important factor to secure accuracy using its empirical line calibration. Although, inherent differences in spectral and radiometric properties of tested cameras lead to variations in measured reflectance factors. As fact, accommodating four tested airborne sensors over the same area of interest because of different footprints was a challenge. Mazur and Chojnacki compared compact cameras, DYI IR (Canon S100 Event 38 mod), dedicated, low-cost two-band camera and Parrot Sequoia four spectrum camera used in this research, finding similar problems as Von Bueren et al. [5]. There was found that non-professional camera cannot provide qualitative data for interpretation.

According to Capolupo et al., using hyperspectral imaging and continuous reflectance spectrum can be adopted to characterize both structural and biochemical traits of grassland [2]. Using UAV and hyperspectral imagery can be used to maintain health status of grassland ecosystem, suggesting Partial Least Squares Regression (PLSR) as best statistical multivariate regression technique for explaining the relationship between hyperspectral data variables and grassland traits. Grassland canopy height can be measured remotely with the use of DSM, crop model using UAV. Borra-serrano et al. compared herbometer readings with DSM model achieving correlations from 0,517 to 0,625, which is quite good result [1]. However, Grenzdörffer who tested crop height determination with UAV achieved low correlation with VARI (Visible Atmospherically Resistant Index) which uses RGB (visible light) data [3].

2. Aim of study

Aim of this early stage research was attempt to estimate correlation between grassland fresh biomass and multispectral indices to develop nondestructive, remote measurement method of grassland yield to substitute inefficient, high-cost hand-measurements with usage of herbometer which method highly restricts common grasslands monitoring

3. Materials and methods

For research 60 ha grassland area has been selected (Rega river valey, close to Lobez, West Pomerania, 53°37’56.49”N, 15°35’04.48”E). All measurements have been done on 24th of May 2018. Multispectral measurements have been taken with Parrot Sequoia four-band camera (R, G, REDEDGE, NIR), Mazur and Chojnacki [6]. It is compact, GoPro sport camera size unit with extra GPS receiver (for picture geotagging) and four band ambient light sensor for sun light compensation. Camera has its own auto triggering system (time or distance based). Camera was carried by AGRODRON® X4 quadcopter (5 kg MTO) which performed measurements taking picture at 300 meters with appropriate overlap and sidelap (80%) land coverage, achieving 30cm/pix resolution, IMU (internal measurement unit) with gyro to analyze and record angles of camera (no gimbal installed) and sun and pictures angles, which are used for proper data processing. Pictures set (356 pictures, four TIFF files for one shot, for particular bandwidth) have been processed in dedicated software (Pix4Dag) to produce mosaic map and calculate spectral indices. Additionally, RGB pictures set has been taken with Sony ILCE 6000 camera (24 MPx, 6000x4000 pix resolution) and processed in PixDAg for visual judgment. The RGB map of survey area is presented in Fig. 1.

Source: own work / Źródło: opracowanie własne

Fig. 1. RGB map of survey area
Rys. 1. Mapa RGB obszaru pomiarowego

Fig. 2 presents the NDVI map of survey area of grassland.

Down sampled vector indices map (SHP, 1 meter resolution grid) has been exported from Pix4Dag software for ground survey. Manually selected points of interest on indices map have been selected and survey has been planned in FarmWorks Maping software. Using handheld computer with GPS receiver and Farmworks Mobile survey software with planned points, plant canopy biomass in selected destinations of grassland has been tested and statistically compared with given indices.

Do-It-Yourselves herbometer (grass canopy density/biomass meter) has been developed.

It is commonly used measurement but rather for scientific purposes than practical because of its performance. Measurement plate of 50 cm diameter and weight of about 360 grams moves smoothly by the guidance pipe. Distance from ground to plate freely sustained on the canopy has been measured indirectly by measurement of the distance between laser distance meter (BOSCH PLR50C) and the plate.

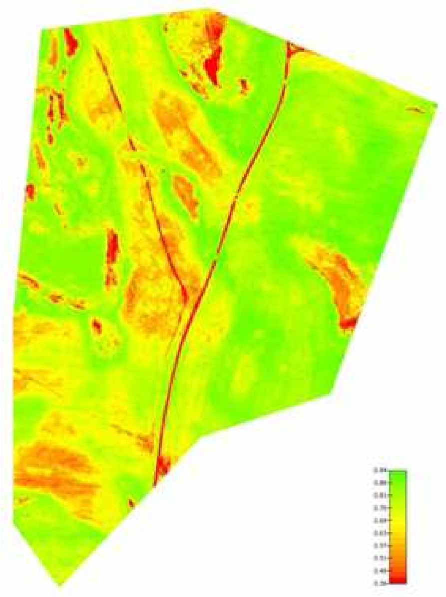

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Fig. 2. NDVI map of survey area of grassland

Rys. 2. Mapa NDVI obszaru badań użytków zielonych

Therefore herbometer had so heavy plate that grass canopy bend under weight of the plate. Device used for grass measure is presented in Fig. 3.

Source: own work / Źródło: opracowanie własne

Fig. 3. Herbometer with laser distance meter

Rys. 3. Herbometr z laserowym pomiarem odległości

4. Results

To perform measurements 16 points in the pasture were selected. The results of the grass height measurements and corresponding them NDVI values are shown in Table 1. These results were transferred to the chart in the Fig. 4. A regression equation describing the relationship between the results obtained from the herbometer and NDVI indicators has been determined by mathematical formula (2):

$$Y = 0{,}0011 \cdot x + 0{,}2337 \quad (2)$$

where: Y in this equation means NDVI value,
x is grass height measurements from herbometer.

For the obtained linear equation model, the correlation coefficient of R^2 was 0,7507.

Linear equation best described correlation, higher order equations where less correlated.

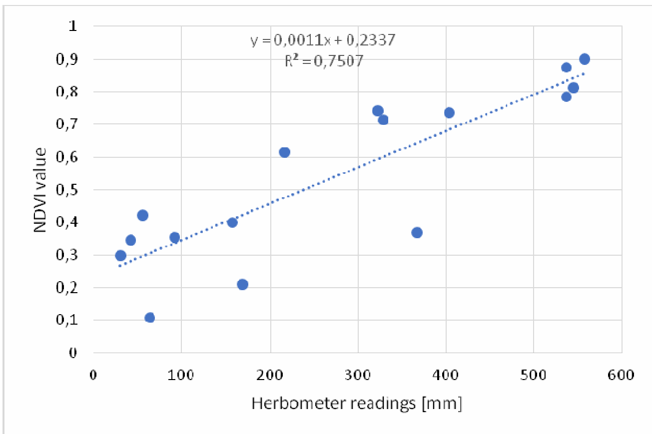
Research has shown that there is a mathematical relationship between the NDVI coefficient values and the grass height in the pasture.

Tab. 1. Results of grass height measurements using herbometer and NDVI values.

Tab. 1. Wyniki pomiaru wysokości trawy za pomocą herbometru i wartości wskaźnika NDVI

Item	Herbometer values [mm]	NDVI values
1.	537	0,876
2.	323	0,741
3.	55	0,423
4.	545	0,813
5.	404	0,736
6.	157	0,399
7.	30	0,298
8.	42	0,347
9.	329	0,714
10.	64	0,107
11.	367	0,369
12.	169	0,21
13.	558	0,901
14.	537	0,786
15.	217	0,615
16.	92	0,354

Source: own work / Źródło: opracowanie własne



Source: own work / Źródło: opracowanie własne

Fig. 4. Relationship between NDVI values and herbometer measurements

Rys. 4. Zależność pomiędzy wartościami wskaźnika NDVI a wskazaniami herbometru

5. Discussion

Researched fast and non-destructive grassland biomass measurement method with usage of small UAV and multispectral camera shows it as comprehensive for management and conservation of grasslands. It can be promising tool for farmers, advisers, government institution to conserve grasslands area. Access to low cost UAVs and multispectral cameras open this solution for wide range of actors.

Although, further development and validation are needed to increase quality and repeatability of method, e.g. influence the time of day when multispectral measurement are being taken, which spectral indices (in paper only NDVI as most popular has been considered) best correlate with grass biomass, growth stage limits etc.

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Authors own resources.