Plant and Soil Science

Journal homepage: https://agriculturalscience.com.ua/en
Plant and Soil Science, 12(2), 47-53
Received xx.xx.2021 Revised xx.xx.2021 Accepted xx.xx.2021

UDC 631.547
DOI: 10.31548/agr2021.02.0047

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Methodological approaches to identifying plants on high resolution images of multispectral monitoring using UAVs

Abstract. Plant growers need accessible and effective information about the state of crops to implement crop management. The purpose of the study is to develop a method for identifying plants on high-resolution multispectral images for continuous sowing crops, using the example of winter wheat. The studies are conducted in the Left-Bank Forest-Steppe zone, on industrial crops of winter wheat, Mulan variety. At the time of remote monitoring through UAVs (2019.03.17), the plants were in the tillering stage. Monitoring from an altitude of 100 meters is conducted using the Slantrange 3p spectral system installed on the DJI Matrice 600 UAV. A full-screen copy of the snapshot window is made to extract reference graphic data from the SlantView programme. Statistical processing of graphical data of spectral monitoring results is performed in the MathCad programme. It is noted that reliable determination of the spectral portrait of the soil for its pixel filtration from multispectral images is a difficult task, since its colour substantially depends on the state of moisture and may differ in open and shaded areas. A fundamentally new way to filter out random inclusions is to use a spectral portrait of plants based on the intensity ratios of their components. A promising parameter for assessing the condition of crops is the estimation of their horizontal surface area, which can be determined by pixel-by-pixel image analysis. A filtering option that requires debugging is suggested.

Suggested Citation:
Pasichnyk, N.A., Lysenko, V.P., & Opryshko, O.O. (2021). Methodological approaches to identifying plants on high resolution images of multispectral monitoring using UAVs. *Plant and Soil Science*, 12(2), 47-53. doi: 10.31548/agr2021.02.047.

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In further studies, it is advisable to consider the issue of methodological support for assessing the quality of filtering data from spectral monitoring of plantings.

Keywords: Slantrange, crop identification, filtering

INTRODUCTION

The relevant criterion of optimality for crop production in a market economy is the rational consumption of funds and energy, which implies the introduction of precision farming technologies. Crop management is one of the key trends in the modernisation of technologies in crop production. Plant growers need accessible and effective information about the state of crops to implement crop management. The monitoring technologies currently used require serious methodological findings. For ground-based equipment such as the Yara N-Sensor presented by (Matveenko *et al.*, 2017) data is available because it can be obtained promptly in the right place in a format acceptable for technical implementation, but inefficient because it is not adapted to industrial scale. Setting up such ground-based equipment provides for the optimal criterion – maximum yield. Satellite technologies are effective because they will allow getting information for the entire field, but are limited because they depend on weather conditions and have a high cost even with an average image resolution. Unmanned aerial vehicles (UAVs) also have their limitations, but for crop monitoring, this is undoubtedly a revolutionary solution. Unlike satellite technologies, they can work under the cloud and allow getting high-resolution images at an affordable price. One of the reasons constraining the introduction of these monitoring technologies is the complexity of using spectral sensor equipment for measurement purposes to make a decision on the use of ground-based equipment. In the initial stages of vegetation, when it is possible to effectively manage the crop, vegetation indices will depend on the condition of the soil and the presence of plant residues recorded in the images (Pasichnyk *et al.*, 2020), which affects the reproducibility of the results. There are serial multispectral systems, such as Slantrange, where developers in proprietary software offer a system for filtering soil and foreign objects, but its configuration is based on a visual assessment of the image, while the filtering algorithm implemented by the developer is closed. In general, existing remote air and satellite monitoring technologies have substantial problems, primarily of a methodological nature. Thus, according to the results of the study (Duan *et al.*, 2017) by combining data from GreenSeeker ground-based equipment and a UAV-mounted RedEdge camera, a substantial difference was recorded for the NDVI index, which had both static and dynamic components, which was recorded at different stages of vegetation. The authors made adjustments to consider old leaves to increase the correlation, but in the initial stages of vegetation, when the plant dome is not dense and a substantial percentage of soil is captured, reproducibility will decrease. This phenomenon is due to the fact that the spectral parameters of the soil, both in the visible and infrared ranges, depend on the state of its moisture content, which can change over several hours. The results were confirmed in the experiments (Zhelezova *et al.*, 2016), where it was identified that during the autumn and spring tillering period, the results of measurements from the GreenSeeker® RT200 ground sensor and the Canon S110 NIR camera installed on the UAV were close in row spacing of 12 cm, and for 18 cm they had a substantial difference. During the tillering growing stage, a stable difference in indicators was present, regardless of the width of the row spacing, which the authors explain by different lighting conditions. This explanation is debatable, since the monitoring height did not depend on the stage of vegetation, and the characteristic difference in sensor indicators was recorded with a larger row spacing width. A possible explanation for this is soil capturing during aerial monitoring. Soil can be identified by the pixel-by-pixel analysis, as shown in the papers (Komarchuk *et al.*, 2019; Xiuliang Jin *et al.*, 2017). An example of such indices for wheat identification are the ExG, EGVI, and ERVI presented in the paper, which were used by developers for the image resolution of 0.2 mm/pixel. However, for industrial monitoring systems, lower resolution image distinguishing is more suitable, as shown in the paper (Linyuan *et al.*, 2018). The infrared range is used as part of the ground line concept to identify plants from satellite imagery, so it can also be effective for UAVs, which needs to be checked. Based on this, ***the purpose of the study*** is the development of a method for identifying plants on multispectral images of high resolution for continuous sowing crops, using the example of winter wheat.

MATERIALS AND METHODS

The above survey was conducted on 2019.03.17 on industrial crops of winter wheat, Mulan variety, geographically in the Left-Bank Forest-Steppe zone (50º16 'N, 30º58'E). The plants were in the tillering stage. The exposed areas of soil were in an air-dry state. Two areas without vegetation were selected (dried lowland – "saucer") were used to conduct research on the effect on the spectral parameters of wet soil, one of which was previously abundantly moistened so that 15 minutes before the flight, the puddles would not be visible from the ground level.

Aerial monitoring was conducted using the Slantrange 3p spectral system installed on the DJI Matrice 600 UAV. The flight altitude is 100 meters, which provided a spatial resolution of 14 mm/pixel for each of the channels. The Slantrange 3p system has 4 monochrome measurement channels (Green, Red, RedEdge, iRed) and a standard lighting correction system based on an areal sensor. Specialised SlantView software allows calibrating the results of photography by lighting and positioning and creates maps of the distribution of vegetation indices (VI). Since the programme does not provide access to the distribution map by source channels, an additional interface of the snapshot window was used. Figure 1 shows the SlantView snapshot windows in the green channel (left) and in pseudo-colours (right), with the areas under study highlighted directly in the programme.

A full-screen copy of the snapshot window was made to extract reference graphic data from the SlantView programme, which was saved in the Windows 7 pro Paint image editor in bmp format (24 bits). Cropping the image with positioning on reference points was done in the MS Office Picture manager programme. Statistical processing of graphical data of spectral monitoring results was performed in the MathCad (ver.14) programme according to the methodology presented in the paper (Pasichnyk *et al.*, 2019) [8]. In the programme, the original bmp or jpeg image was first converted to a matrix, which allowed clearly identifying each pixel of the image, and then the number of pixels for each of the 256 gradations of colour intensity was counted.

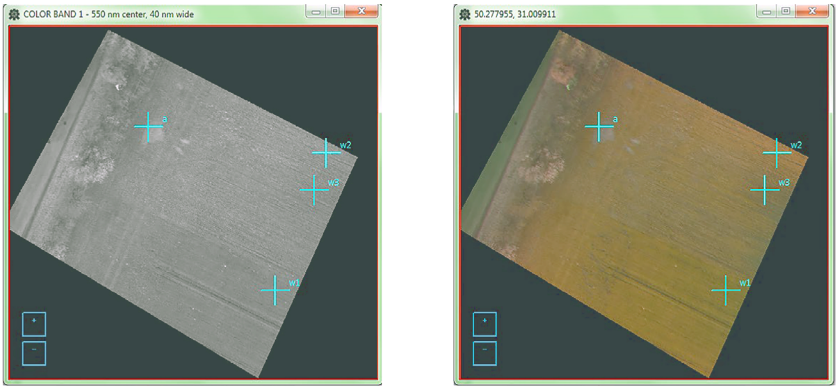

Figure 1. SlantView snapshot window interfaces:
on the left – a monochrome image in the green channel (530-570 nm), on the right – an image in pseudo-colours (without the blue channel). Designations on placemarks set by the operator: *a – open ground in an air-dry state, w1 – without prolonged action of herbicides, w2 – poorly affected areas, w3 – areas with maximum plants affected.*

RESULTS

A programme was written that counted the number of pixels based on the intensity of the colour components for the selected area to set up soil filtration during the analysis. The results obtained are shown in Figure 2.

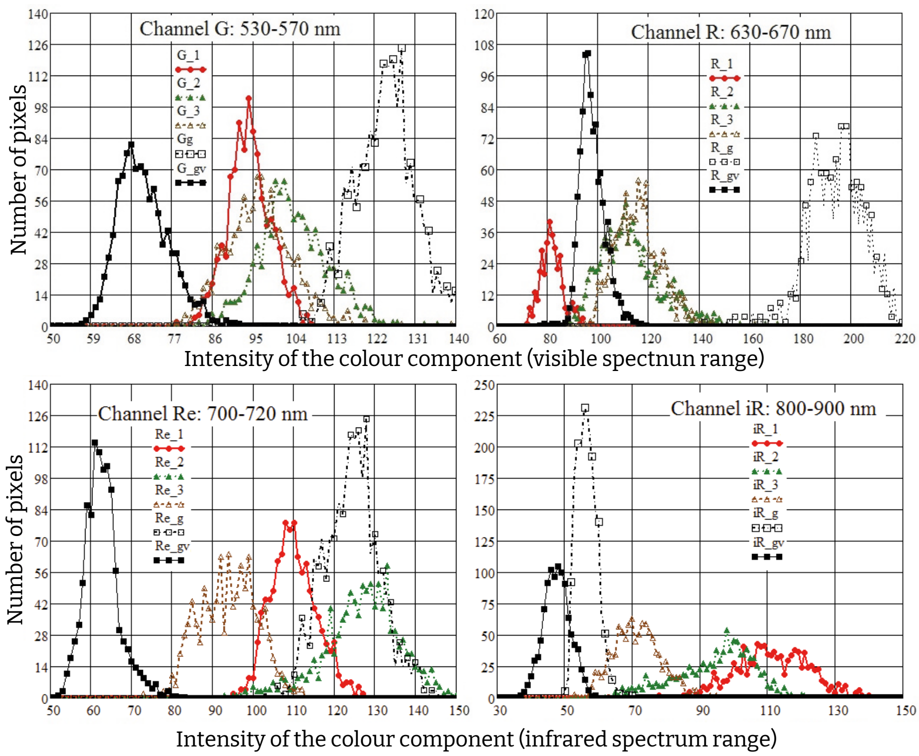

Figure 1. Distribution of the number of pixels depending on the intensity of the colour component
where: *1-3 – wheat, g – dry soil, and gv – wet soil*

Given the results obtained, it is problematic to reliably determine the soil parameters for filtration exclusively through a separate channel. If there are matches for an area with sparse vegetation for the iR channel with dry soil, but not with wet soil, then the opposite happens for the red one. A possible reason for this is the different topography of the soil in arable land and lowland. In addition, the soil in the shade of plants can also have an intermediate state of drying. When considering the prospects for the industrial application of this technology, it is necessary to consider the difficulties in determining soil filtration.

Considering possible variations in soil types and subtypes, a greater versatility of the identification method can be obtained by filtering not soil from the total mass, but by the spectral portraits of the plants. For the plants under study, the value of the G component is lower or close to iR, in contrast to dry or wet soil. According to this assumption, to identify plants, it is proposed to filter out pixels for which the iR-G ≥ F condition is not met. The value of F is configurable and can be determined by the characteristics of the variety (crop). The results obtained are presented in Table 1.

Table 1. Dependence of the spectral parameters of plots and the calculated plant area (S) on the plot on filtration parameters

F	1					2					3				
	G	R	Re	iR	S,%	G	R	Re	iR	S,%	G	R	Re	iR	S,%
-20	94	81	110	111	100	103	111	128	97	83	93	110	98	77	18
-15	94	81	110	111	100	103	110	129	100	67	94	109	102	82	4
-10	94	81	110	112	99	102	109	129	102	50	93	108	104	86	0.5
-5	94	81	110	112	98	101	108	129	104	33	93	108	104	86	
-0	94	80	110	112	95	101	107	129	107	20	93	108	104	86	

By evaluating the effect of filtering on spectral parameters, it was identified that the largest adjustment occurred in the R and iR channels, which will affect the vegetation indices based on them. Interesting are the results of the calculated horizontal area of plants, which has changed substantially, which can be used to assess the condition of plants as an additional parameter.

THE PROSPECTS OF FURTHER RESEARCH

The authors proposed a filtering option, which, just like in solutions implemented in the SlantView software, requires debugging.Debugging is conducted in expert mode, which determines subjectivity, and there are no objective criteria for evaluating the quality of filtering. Therefore, in further studies, it is advisable to consider the issue of methodological support for assessing the quality of filtering data from spectral monitoring of plantings.

CONCLUSIONS

- Reliable determination of the spectral portrait of the soil for its pixel-by-pixel filtration from multispectral images is a difficult task since its colour substantially depends on the state of moisture, which can vary in open and shaded areas.
- A more promising way to filter out random inclusions is to use a spectral portrait of plants, namely the intensity ratios of their components.

n A promising parameter for assessing the condition of crops is the estimation of their horizontal surface area, which can be determined by pixel-by-pixel image analysis. Preliminary results of the study were presented in the materials of the "Identification of plants in images using unmanned aerial vehicles" of the international scientific-practical conference dedicated to the 125th anniversary of the birth of T.S. Maltsev, 5.11.2020, the city of Kurgan, Belarus [6].

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Методичні підходи до ідентифікації рослин на знімках високої роздільної здатності багатоспектрального моніторингу з використанням БПЛА

Анотація. Рослинники потребують доступної та ефективної інформації про стан посівів для здійснення управління посівами. Метою роботи є розробка методу ідентифікації рослин на мультиспектральних знімках високої роздільної здатності для культур суцільного посіву на прикладі озимої пшениці. Дослідження проводяться в зоні Лівобережного Лісостепу, на промислових посівах озимої пшениці сорту Мулан. На момент проведення дистанційного моніторингу за допомогою БПЛА (2019.03.17) рослини перебували у фазі кущіння. Моніторинг з висоти 100 метрів проводиться за допомогою спектральної системи Slantrange 3p, встановленої на БПЛА DJI Matrice 600. Повноекранна копія вікна знімка робиться для вилучення еталонних графічних даних з програми SlantView. Статистичну обробку графічних даних результатів спектрального моніторингу виконано в програмі MathCad. Відзначено, що достовірне визначення спектрального портрета ґрунту для його піксельної фільтрації за багатоспектральними знімками є складним завданням, оскільки його колір суттєво залежить від стану зволоження і може відрізнятися на відкритих і затінених ділянках. Принципово новим способом фільтрації випадкових включень є використання спектрального портрета рослин на основі співвідношення інтенсивностей їхніх компонентів. Перспективним параметром для оцінки стану посівів є оцінка площі їх горизонтальної поверхні, яка може бути визначена шляхом попіксельного аналізу зображення. Запропоновано варіант фільтрації, який потребує налагодження. У подальших дослідженнях доцільно розглянути питання методичного забезпечення оцінювання якості фільтрації даних спектрального моніторингу насаджень

Ключові слова: Косокутний радар, ідентифікація сільськогосподарських культур, фільтрація