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# AERIAL MULTISPECTRAL IMAGING FOR DETECTION AND QUANTIFICATION OF WEEDS

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***Abstract***

*Multispectral remote sensing is a new effective technique to evaluate crops phenology, plant health and the weeds presence. The study aims to exploit the possibilities of multispectral imaging for detection the weeds in winter wheat. The phenological changes of different weeds was also investigated, employing the calculation of six vegetation indexes during a period of three months. The vegetation indexes were as follows: CIG, GRNDVI, GRVI, CVI, NDWI2, NDVI. The influence of weed species on the value of the corresponding vegetation index within each reporting period was investigated. The control value was the one calculated for areas sown with wheat without weeds. It is established that the factors: phenophase and weed type have a statistically significant influence on the researched indexes. The GRVI is the only index on which plant phenophase does not have a significant effect. Regarding the NDVI values, no permanent trend for the presence/absence of a certain weed was found. In almost all phenophases, high values of the index were calculated in both weed varieties and weed free wheat.*

***Key words***: *multispectral imaging, vegetation indices, wheat, weeds.*

## INTRODUCTION

Remote sensing offers new perspectives and methodological approaches for precision agriculture (Baranyai and Firtha, 1997; Láng et al., 2000; Felföldi et al., 2001; Tamás, 2001; Németh et al., 2004; Fekete et al., 2004; Jung et al., 2006).

Reflected solar radiation in specific visible, near, and mid-infrared ranges of the electromagnetic spectrum has proven useful in detecting nutrient deficiencies, diseases, enemies, and weeds (Hatfield and Pinter, 1993; Johnson et al., 2003; Panda and Hoogenboom, 2009; Ray et al., 2006; Usha and Singh, 2013). Weeds are one of the factors limiting the growth and development of cultural plants, including wheat. Depending on the type of weeds and their density, harvest from the crop can decrease by up to 70% (Mitkov, 2023; Manilov, 2022; Yanev, 2022; Yanev et al., 2021; Mitkov et al., 2017).

Information on the distribution of weeds in the field is necessary for the compilation of an evaluation map of crops to determine whether they have reached their biological threshold of harmfulness. Perez et al. (2000) proposed two approaches for automatic weed monitoring:

- Coarse identification of weeds in the monitored areas by remote sensing.
- Fine identification using proximal methods, such as video imaging and image analysis, which should confirm the location and allow the most appropriate local treatment of the crop to be selected. A review of the potential of remote sensing techniques for crop protection suggests that one way to distinguish between weeds and crops is by examining the temporal patterns of vegetation indices over the growing season (Hatfield and Pinter, 1993). Furthermore, using distance methods, usually only a few weed species can be distinguished in different phenophases. A multispectral (hyperspectral) camera mounted on a low-flying aircraft up to 500-700 m above the ground and on a ground vehicle 10 m above the ground can be used to detect and distinguish weeds. Spectral characteristics of weeds should be taken from native populations in weed groups established shortly before the detection process, as characteristics are highly variable and depend on the phenophase of weeds or weed associations (Brown et al., 1994). Two approaches are commonly used for automatic weed monitoring. The first is to detect certain geometric

differences between the crop and the weed, such as leaf shape or plant structure (Guyer et al., 1986; Shearer et al., 1990; Meyer et al., 1998; Ahmad et al., 1999; Burks et al., 2000; Mao et al., 2003). The second approach is based on differences in spectral reflectance. There may also be a difference in the location of the crop compared to weeds (Thompson et al., 1990).

Gueyr et al. (1986) investigated the feasibility of using leaf shape for plant identification. Franz et al. (1991) used local spectral characteristics of plant leaves to distinguish between several weed species.

Vrindts and De Baerdemaeker (1997) showed that discrimination between young crop plants and weeds is possible by spectral reflectance analysis using specific wavelengths in the 200 to 2000 nm range. Some studies on weed detection have included artificial neural networks to distinguish between weeds and crops (ElFaki et al., 1997; Yang and Prasher, 1997). Perez et al. (2000) mainly used color information and shape analysis techniques to detect broadleaf weeds in cereal crops, under real field conditions. In the context of precision agriculture, weed detection using image processing techniques shows good potential for estimating weed distribution, despite difficulties due to the similarity in spectral reflectance between weeds and crop plants, as well as the high variability of natural scenes that should be considered.

In recent years, the development of UAV-based multispectral and hyperspectral remote sensing systems has made rapid progress (Aasen et al., 2018). Compared to systems based on manned aircraft, the sensors are smaller, lighter and cheaper (Manfreda et al., 2018).

It is clear that more research is necessary for precise identification of weeds using remote sensing data. In particular, UAV-supported remote sensing enables highly accurate monitoring of individual areas through lower flight altitude and high-resolution data (Hunt and Duaghtry, 2017). Thus the UAV remote sensing data could be used to overcome the difficulties due to the similarity in spectral reflectance between weeds and crop plants.

The research described in this article aims to investigate the possibilities of multispectral imaging for detection the weeds in winter wheat.

## MATERIALS AND METHODS

The field plot trial was carried out at the experimental base of the Agricultural University of Plovdiv. This study was carried out using ***Survey3W Camera Red+Green+NIR***, which can record images at Green (550 nm), Red (660 nm) and Near Infrared (850 nm) mounted on a drone ***DJI Mavic Air*** from 5 m height. Nine measurements were made over a period of 3 months (April, May and June) at regular 10 days intervals. Thus it was ensured that multispectral images of different phenophases of the wheat and of the weeds were recorded, and investigated. Six vegetation indexes were calculates as given in the Table 1.

Table 1. Formulas used to calculate the investigated vegetation indexes

| Index | Values | Application |
|---|---|---|
| Chlorophyll Index Green $CIG = \frac{NIR}{G} - 1$ | [0; ∞] | Vegetation – chlorophyll, LAI |
| Green-Red NDVI $GRNDVI = \\ = \frac{(NIR - (G + R))}{(NIR + (G + R))}$ | [-1; 1] | Vegetation |
| Normalized Green Red difference index $GRVI = \frac{(G - R)}{(G + R)}$ | [-1; 1] | Vegetation |
| Chlorophyll Vegetation Index $CVI = \frac{(NIR * R)}{(G * G)}$ | [0; ∞] | Agriculture; Vegetation – chlorophyll. |
| Normalized Difference Water Index 2 $NDWI\ 2 = \frac{(G - NIR)}{(G + NIR)}$ | [-1; 1] | Detection of open water |
| Normalized Difference Vegetation Index $NDVI = \frac{(NIR - R)}{(NIR + R)}$ | [-1; 1] | Agriculture – crop parameters, crop yield; Vegetation – biomass, cellulose, lignin, starch, stress, vitality, water. |

The influence of the type of weeds on the value of the respective index within each reporting period was investigated, and the control value was that calculated for areas sown with wheat and unreported presence of weeds of any kind. One-way analysis of variance and LSD-test were applied to evaluate differences at a statistical significance level of 0.05. Mathematical-statistical processing of the experimental data was performed using the SPSS 24 program.

## RESULTS AND DISCUSSIONS

As a result of the applied analyzes it is proved that the value of CIG in the presence of only *Avena fatua* L. or *Anthemis arvensis* L. is significantly lower than that of pure wheat, and in the presence of a greater variety of weeds the values are above 1.3 (Table 2). The GRNDVI index takes negative values, being reliably different in value for pure wheat, for *Avena fatua* L. and *Anthemis arvensis* L., as well as for their combination. The presence of weeds significantly lowers its value. The calculated values of GRVI for pure wheat and the presence of weeds show the presence of proven differences with the basement and with the addition of more than one weed of the indicated species. The CVI has higher values than the control in the case of *Anthemis arvensis* L. and a combination of *Anthemis arvensis* L. and *Avena fatua* L., and lower values in the presence of only one of the two weeds. The value of NDWI2 for pure wheat differs reliably from all others, with a combination of several weeds, this value is less than -0.356, and in the presence of a single weed, it is positively pure. No differences were demonstrated between NDVI value and pure wheat only in a wide variety of weeds. Its value is negative if *Avena fatua* L.or *Anthemis arvensis* L. are found.

In the second reporting period, the values of CIG, GRNDVI, GRVI and CVI differed statistically significantly at the 0.05 level from that of the control, and NDWI2 had no differences with it only in the presence of multiple weeds at the same time. Here, the presence of *Avena fatua* L. or *Anthemis arvensis* L. implies a positive index, which in the case of pure wheat is negative, and this is an indicator of the presence of the corresponding weed. The NDVI index of pure wheat was 0.229, which was significantly higher than the negative ones of *Avena fatua* L. and *Anthemis arvensis* L., therefore significantly different from the control area.

In the third reporting period, *Avena fatua* L.-dominated areas had a CIG value that was not different from wheat-only areas, but the presence of one of the two weeds was found to imply values less than 1, and those with diversity of weeds - higher than 1.484 (control area - corresponding value 1.334). The values of the indices: GRNDVI, GRVI, NDWI2 and NDVI were demonstrably different from those of pure wheat (-0.027; -0.172; -0.390 and 0.236, respectively) in the presence of only one of the two weeds.

In the fourth period, the values of all indices were not demonstrably different from those of pure wheat, except for the presence of only *Avena fatua* L. When GRNDVI is less than one, it is an indicator of presence of *Avena fatua* L. CVI values less than 2 signal the presence of wild oats, and greater than 4 a variety of weeds, although they have no statistically significant differences with pure wheat. The fifth reporting period is characterized by a lack of proven differences between the areas with pure wheat and those with *Anthemis arvensis* L. in all the investigated indicators. Statistically significant differences were proven between the areas free from weeds and those with a large variety of them, the latter possessing indices, significantly exceeding those of pure wheat (except for NDWI2, which was negative for each type of area and less than the control).

During the sixth research period, a statistically significant difference was established between the values of all indices calculated for areas without weeds and those with weeds, regardless of their type, as well as a wide variety of them. In addition, the value of GRNDVI (below 0.5), GRVI (below -0.202) and CVI (below 2) was significantly lower in the presence of some weeds than in the absence of them. The remaining indices have correspondingly higher values than those of pure wheat.

The value of CIG for pure wheat during the eighth reporting period is negative, and for the presence of *Anthemis arvensis* L. - positive, which determines the presence of proven differences between them and is an indicator of the presence of the corresponding weed on the given area. GRVI and NDVI are positive only for *Anthemis arvensis* L.

During the last reporting period, no proven differences are shown between *Avena fatua* L. and pure wheat for all indices studied, making it an inappropriate period to establish a presence of weeds on a given plot. There are proven differences between the control area and the plots with *Anthemis arvensis* L. for the indices CIG, GRNDVI (where they were much higher than for pure wheat), GRVI, NDWI2 (lower than for pure wheat), and NDVI.

Based on the measurements and analyses, it should be considered that, if the measurement is carried out in the first, second, third or fourth period, the CIG value is less than 0.9 for areas with *Avena fatua* L. Values below 0.9 in the fifth and sixth periods are an indicator of the presence of *Avena fatua* L. and/or *Anthemis arvensis* L., and in the last three periods - values above 0.2 are determined by the presence of weeds. Positive values of GRNDVI during the first five periods are due to the presence of weeds in wheat.

Table 2. Influence of the type of weeds on the indices during the corresponding reporting and measurement period

| Measure-ment № | Weed | CIG | GRNDVI | GRVI | CVI | NDWI2 | NDVI |
|---|---|---|---|---|---|---|---|
| 1 | Avena fatua L. | 0,015* | -0,358* | -0,055[n.s.] | 1,161[n.s.] | 0,001* | -0,055* |
| | Anthemis arvensis L. | -0,482* | -0,593* | -0,003* | 0,522* | 0,326* | -0,328* |
| | Wheat with Avena fatua and Anthemis arvensis | 1,671* | 0,002* | -0,178* | 4,252* | -0,409* | 0,259* |
| | Mixture of weeds | 1,351[n.s]. | -0,056[n.s.] | -0,165* | 3,775[n.s.] | -0,356* | 0,211[n.s.] |
| | Wheat only | ***0,834*** | ***-0,147*** | ***-0,100*** | ***2,492*** | ***-0,231*** | ***0,143*** |
| Sign. | | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 |
| 2 | Avena fatua L. | 0,016* | -0,392* | -0,040* | 1,165* | 0,075* | -0,120* |
| | Anthemis arvensis L. | -0,159* | -0,434* | -0,024* | 0,874* | 0,121* | -0,141* |
| | Wheat with Avena fatua and Anthemis arvensis | 1,764* | 0,042* | -0,179* | 4,237* | -0,448* | 0,298[n.s.] |
| | Mixture of weeds | 1,602* | 0,041* | -0,150* | 3,599* | -0,436[n.s.] | 0,307[n.s.] |
| | Wheat only | ***1,042*** | ***-0,063*** | ***-0,102*** | ***2,603*** | ***-0,320*** | ***0,229*** |
| Sign. | | 0,000 | 0 | 0 | 0 | 0 | 0 |
| 3 | Avena fatua L. | 0,391[n.s]. | -0,220* | -0,032* | 1,595[n.s] | -0,133* | 0,104* |
| | Anthemis arvensis L. | 0,492* | -0,179* | 0,002* | 1,585[n.s] | -0,150* | 0,154* |
| | Wheat with Avena fatua and Anthemis arvensis | 2,058* | 0,039[n.s.] | -0,205[n.s] | 5,470* | -0,451[n.s] | 0,285[n.s] |
| | Mixture of weeds | 1,484* | -0,044[n.s.] | -0,214[n.s] | 4,369[n.s] | -0,395[n.s] | 0,203[n.s] |
| | Wheat only | ***1,334*** | ***-0,027*** | ***-0,172*** | ***3,402*** | ***-0,390*** | ***0,236*** |
| Sign. | | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 |
| 4 | Avena fatua L. | 0,625* | -0,149* | -0,065* | 1,907[n.s] | -0,224* | 0,163* |
| | Anthemis arvensis L. | 1,274[n.s] | -0,021[n.s] | -0,124[n.s] | 3,051[n.s] | -0,370[n.s] | 0,260[n.s] |
| | Wheat with Avena fatua and Anthemis arvensis | 1,558[n.s] | -0,005[n.s] | -0,148[n.s] | 4,019[n.s] | -0,390[n.s] | 0,267[n.s] |
| | Mixture of weeds | 1,880[n.s] | 0,035[n.s] | -0,192[n.s] | 4,783[n.s] | -0,446[n.s] | 0,288[n.s] |
| | Wheat only | ***1,283*** | ***-0,042*** | ***-0,161*** | ***3,382*** | ***-0,369*** | ***0,226*** |
| Sign. | | 0,007 | 0,001 | 0,040 | 0,017 | 0,002 | 0,001 |
| 5 | Avena fatua L. | 0,557[n.s] | -0,152[n.s] | 0,002* | 1,648[n.s] | -0,183* | 0,187[n.s] |
| | Anthemis arvensis L. | 0,866[n.s] | -0,090[n.s] | -0,066[n.s] | 2,260[n.s] | -0,278[n.s] | 0,220[n.s] |
| | Wheat with Avena fatua and Anthemis arvensis | 1,663* | -0,010[n.s] | -0,210* | 4,542* | -0,420* | 0,236[n.s] |
| | Mixture of weeds | 2,422* | 0,106* | -0,239* | 5,961* | -0,525* | 0,332* |
| | Wheat only | ***0,965*** | ***-0,094*** | ***-0,126*** | ***2,678*** | ***-0,307*** | ***0,191*** |
| Sign. | | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,002 |
| 6 | Avena fatua L. | 0,565* | -0,165* | -0,017* | 1,881* | -0,183* | 0,172* |
| | Anthemis arvensis L. | 0,628* | -0,129* | -0,029* | 1,783* | -0,225* | 0,199* |
| | Wheat with Avena fatua and Anthemis arvensis | 1,229* | -0,037* | -0,119* | 3,026* | -0,350* | 0,247* |
| | Mixture of weeds | 1,438* | -0,019* | -0,178* | 3,746* | -0,399* | 0,241* |
| | Wheat only | ***2,476*** | ***0,085*** | ***-0,257*** | ***6,630*** | ***-0,515*** | ***0,307*** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Sign. | | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 |
| 7 | Avena fatua L. | 0,066* | -0,339* | -0,024* | 1,196* | 0,000* | -0,023* |
| | Anthemis arvensis L. | 0,416 $^{n.s}$ | -0,219 $^{n.s}$ | -0,015* | 1,600* | -0,120 $^{n.s}$ | 0,110 $^{n.s}$ |
| | Wheat with Avena fatua and Anthemis arvensis | 0,291* | -0,286 $^{n.s}$ | -0,114 $^{n.s}$ | 1,694* | -0,109 $^{n.s}$ | -0,004 $^{n.s}$ |
| | Mixture of weeds | 0,262* | -0,295* | -0,104* | 1,657* | -0,095* | -0,007 $^{n.s}$ |
| | Wheat only | ***0,647*** | ***-0,202*** | ***-0,156*** | ***2,373*** | ***-0,217*** | ***0,067*** |
| Sign. | | 0,020 | 0,018 | 0,000 | 0,012 | 0,008 | 0,011 |
| 8 | Avena fatua L. | -0,033 $^{n.s}$ | -0,409 $^{n.s}$ | -0,074 $^{n.s}$ | 1,191 $^{n.s}$ | 0,061 $^{n.s}$ | -0,132 $^{n.s}$ |
| | Anthemis arvensis L. | 0,207* | -0,248* | 0,054* | 1,155 $^{n.s}$ | -0,063* | 0,118* |
| | Wheat with Avena fatua and Anthemis arvensis | 0,152* | -0,389 $^{n.s}$ | -0,193* | 1,930* | -0,046 $^{*}$ | -0,150 $^{n.s}$ |
| | Mixture of weeds | 0,016 $^{n.s}$ | -0,419 $^{n.s}$ | -0,165 $^{n.s}$ | 1,517 $^{n.s}$ | 0,013 $^{n.s}$ | -0,176 $^{n.s}$ |
| | Wheat only | ***-0,157*** | ***-0,459*** | ***-0,101*** | ***1,046*** | ***0,101*** | ***-0,199*** |
| Sign. | | 0,028 | 0,000 | 0,000 | 0,008 | 0,027 | 0,000 |
| 9 | Avena fatua L. | 0,116 $^{n.s}$ | -0,352 $^{n.s}$ | -0,127 $^{n.s}$ | 1,466 $^{n.s}$ | -0,044 $^{n.s}$ | -0,082 $^{n.s}$ |
| | Anthemis arvensis L. | 0,242* | -0,247* | -0,001* | 1,310 $^{n.s}$ | -0,094* | 0,092* |
| | Wheat with Avena fatua and Anthemis arvensis | -0,062 $^{n.s}$ | -0,441* | -0,143 $^{n.s}$ | 1,303 $^{n.s}$ | 0,057 $^{n.s}$ | -0,196* |
| | Mixture of weeds | 0,020 $^{n.s}$ | -0,411 $^{n.s}$ | -0,149 $^{n.s}$ | 1,446 $^{n.s}$ | 0,014 $^{n.s}$ | -0,162 $^{n.s}$ |
| | Wheat only | ***0,031*** | ***-0,380*** | ***-0,098*** | ***1,325*** | ***0,004*** | ***-0,102*** |
| Sign. | | 0,016 | 0,000 | 0,000 | 0,800 | 0,015 | 0,000 |

## CONCLUSIONS

The analyzes made make it possible to predict the presence/absence of a certain type of weed in the relevant territory during a specific period of time depending on the value of a given index. Weeds are easier to recognize, depending on the index values, if they are counted in the first six periods, when there is also a higher number of proven differences with the control area. During the last two reporting periods, it would be more difficult to determine the presence/absence of weeds based only on the vegetation indices calculation.

It is established that the factors: phenophase and weed type have a statistically significant influence on the researched indices. The GRVI is the only index on which plant phenophase does not have a significant effect. Regarding the NDVI values, no permanent trend for the presence/absence of a certain weed was found.


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