SOME POSSIBILITIES OF THE AERIAL DRONES USE IN PRECISION AGRICULTURE – A REVIEW

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Abstract: Precision agriculture, together with remote sensing and vegetation indices, represents a modern correlation that maximizes efficiency and sustainability in farmland management, contributing to more efficient and responsible production. Remote sensing in agriculture is an important technology that uses data from sensors mounted on satellites, drones, and aircraft to monitor and evaluate agricultural land. Vegetation indices are needed in agricultural remote sensing and precision agriculture because they provide quantitative and objective information on agricultural crops contributing to more efficient, sustainable and cost-effective land management.

Keywords: drones, remote sensing, precision agriculture, vegetation indices

1. INTRODUCTION

Drones are remotely piloted aircraft systems (RPAS), with propulsion system, a programmable controller with satellite navigation system, automatic flight planning functions and can carry payloads such as cameras, spray systems etc. to perform some specific tasks. Several other acronyms, for these are UAV/UAV (Unmanned Aerial Vehicle/Systems), UAS (Unmanned Aircraft Systems) are used interchangeably. However, RPAS is the most formal way of addressing such systems. Drones used for agricultural activities are known as agricultural drones [1].

For smart agriculture and precision agriculture (PA), aerial remote sensing is one of the most important technologies. Aerial remote sensing (RS), using drones, uses images of different wavelengths and measures vegetation indices to recognize multiple crop conditions [2, 3]. In past decades, manned aircraft or satellites have been used to capture desired images that have been used for precision agriculture [4]. Capturing images using manned aircraft is very expensive, and the problem with satellite images is that the spatial resolution of the images is not as good as desired. In addition, the availability and quality of images depend on weather conditions [5, 6]. A breakthrough in unmanned aerial vehicle (UAV) technologies and the reduction in weight of payload devices has changed the way crops are remotely sensed. This technology is less expensive, saves time and captures high-resolution images in a non-destructive way without requiring direct intervention by agricultural machinery [7].

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Precision agriculture is an approach to agricultural management that uses advanced technologies to boost crop yields, minimize waste, and optimize the use of resources such as water, fertilizers, and pesticides [8-9]. Some of the effective technologies used in precision agriculture include: geographic information system (GIS). This technology is used to map and monitor soil types, nutrient levels, and other key factors on a farm. Farmers can use this information to make informed decisions about planting, fertilization and other management practices [10].

The benefits of using drones in agriculture can be categorized into the following stages (these are just some of these opportunities for use) [11]:
-Crop stage assessment, farmers can use aerial imagery to assess the various crop stages from sowing to harvest. Based on crop progress, farmers can effectively plan for watering needs and pesticide application status. In addition, easy access to this information allows farmers to respond quickly to any issues affecting their plants;
-Soil profile analysis, the 3D maps generated by the drone can aid and assist farmers in determining the health of the soil. This data is essential for farmers to maximize yields because it recognizes which parts of the land are most fertile, which parts remain bare, and which need to be fertilized to improve soil nutrient levels for the next harvest;
-Nutrient and irrigation management, he usage of drones has significantly facilitated discipline analysis, because the information captured through the drones may be entered to discover regions of nutrient and water deficiency.

Drones also are critical for figuring out elements which can be affecting crop boom and making sure that suitable corrective moves are taken. The information furnished through drones can help farmers in phrases of setting up powerful irrigation techniques. These are several usages of drones.

The paper aims were to identify the benefits of drones using in precision agriculture. Also, the focus was to remote sensing and vegetation indices evaluation to increase crop yields.

2. REMOTE SENSING (RS) IN PRECISION AGRICULTURE

Remote sensing is a tool for monitoring the Earth's resources using space technology in addition to ground-based observations. Remote sensing using drones brings significant advantages, offering a more detailed and flexible approach to data collection compared to remote sensing using satellites or aircraft. Some ways in which drones are used for remote sensing in agriculture [12, 13]:
a) High resolution images: drones equipped with multispectral or hyper-spectral cameras can provide high resolution images to assess plant health, soil condition and other relevant features. These images can provide plant-level detail and detect problems on a smaller scale;
b) Real-time crop monitoring: drones allow farmers to collect real-time data on crop condition. This provides the ability to make quick decisions, such as identifying and managing problems such as disease or pest invasions immediately;
c) Heat maps: drones can be equipped with thermal cameras to assess plant and soil temperatures. This is useful for identifying areas of potential heat stress or water deficit.
d) Plant vigor maps: using remote sensing techniques, drones can create plant vigor maps, highlighting variations in the health and development of agricultural crops. This allows farmers to identify and effectively manage variations in the field;
e) Range monitoring: drones can fly at low altitudes, providing a detailed view of agricultural land. This facilitates detailed monitoring of specific areas, such as field margins, where pest problems or water stress may occur.
f) Environmental impact assessment: drones allow farmers to collect data on the impact of environmental factors on agricultural crops, such as the effects of climate change or fluctuations in soil quality;
g) Rapid farmland inspections: drones can carry out rapid inspections of farmland, allowing farmers to identify affected areas or specific problems in a short time;
h) Customize the application of agricultural inputs: data collected by drones can be used to customize the application of agricultural inputs, such as irrigation or fertilizer application, according to the specific needs of each area of the field.

Remote sensing of crops with drones (Figure 1) provides farmers with accurate and up-to-date information for decision-making, helping to optimize resource management and improve crop yields [13].

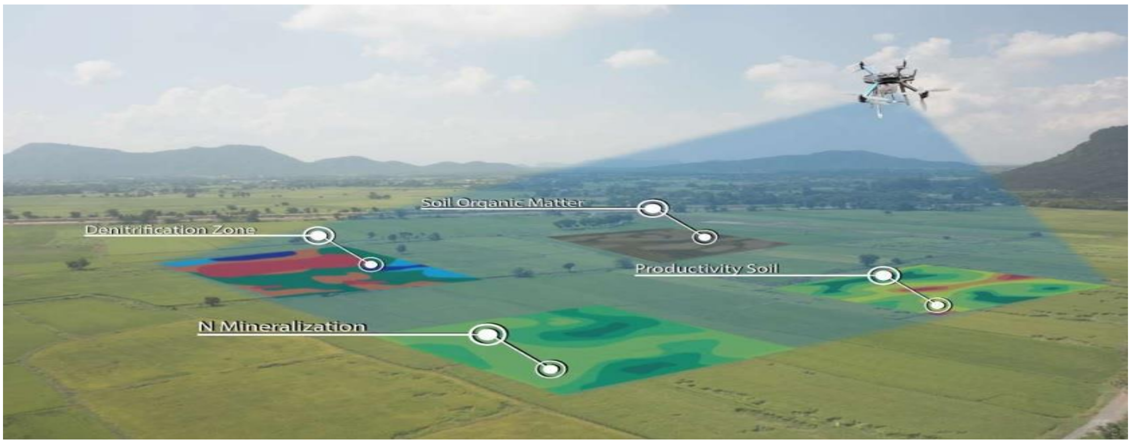

Fig. 1. Drones and precision agriculture [13].

A single drone flight can produce up to 4.000 individual images that are converted into charts usingpost-processing software similar as Pix4D or Agisoft. The images are georeferenced by adding equals to each image for maximum geographic position delicacy and assembled into orthomosaics.

In other words, the software aligns colorful lapping images grounded on geographic equals and reference points, creating 2D and 3D maps Figure 2. The findings can also be used directly or integrated into planning software that provides conventions and recommendations. This ensures smooth and effective decision timber and perpetration grounded on the reused data [14].

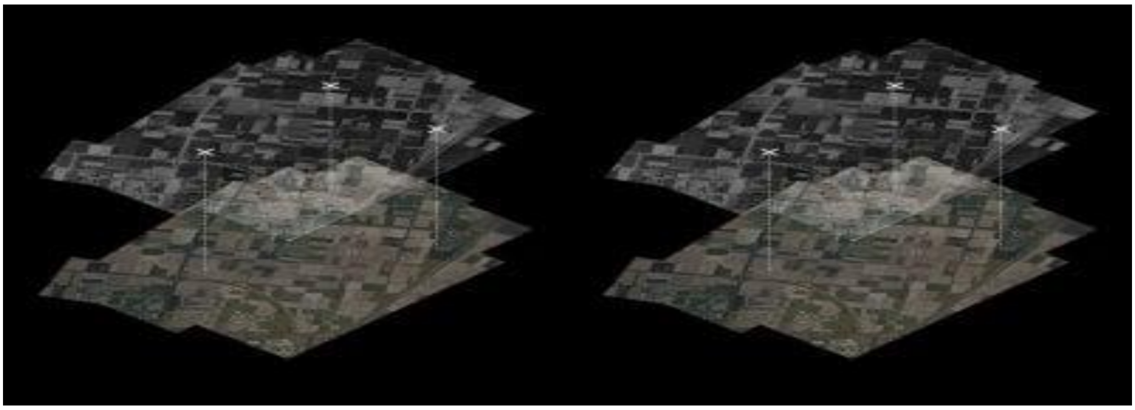

Fig. 2. Superimposed orthomosaic images creating a 2D image [14].

3. DETERMINATION OF VEGETATION CONDITIONS USING VEGETATION INDICES MSAVI, NDVI AND NDRE

There are numerous methods for analyzing data transmitted by drones using multispectral cameras in different frequency bands. Among them, NDSI (regularized Differential Soil Salinity Index) allows to assess the swab content of the soil face, MSAVI (Modified Soil Acclimated Vegetation Index) allows to assess the condition of youthful foliage when the soil face isn't fully covered by foliage, NDVI (regularized Differential Vegetation Index) allows to assess the condition of adult shops and NDRE (regularized Differential Red Spectrum Index) allows as the sophisticated counterpart of the leaf indicator, to evaluate the health and nutritional status of the chlorophyll conditioning at retail establishments. Before seeding and after germination, NDSI and MSAVI are calculated separately.

Early on, these indicators make it feasible to identify potential issue areas and bring them to the attention of experts. Using the NDVI and NDRE indicators, it is vital to ascertain the association between these indicators and the state of the shops during their growth stages. Table 1 provides the computation methods for finding the indicators [15, 16].

Table 1. Formulas for determining NDSI, MSAVI, NDVI and NDRE [15]

Index name	Determination formula
Modified vegetation index adjusted for MSAVI soil	$\frac{2NIR+1-\sqrt{(2NIR+1)^2-8(NIR-RED)}}{2}$
Normalized vegetation differential index NDVI	MIR-NIR/ MIR+NIR
Normalized differential difference index of red NDRE	NIR-REDEDGE /NIR+REDEDGE

The Table 1 notations are:

- *REDEDGE* - band located near the edge of the red spectrum and is often referred to as the red-edge band. The information in this band is extremely useful for identifying subtleties in plant health, such as water stress or other changes in photosynthesis.
- *MIR*- lies between the electromagnetic spectrum's near- and far-infrared regions. This range of data can be useful in assessing several aspects of plants, such as their health, chemical composition, and other distinctive characteristics.
- *RED* - is a red band in the electromagnetic spectrum. The information in this band is useful for assessing the general health of plants and identifying various vegetation characteristics.

The MSAVI for areas with scant vegetation, which corresponds to early crops, it is a reliable indication of vegetation. It is especially useful for early crop condition diagnosis. Nevertheless, a comparison of the vegetation indices of various crop types was done, as shown in Figure 3. In the early stages of plant growth, when open soil takes up more area on the field photos and biomass is still low, MSAVI corrections are more accurate [17].

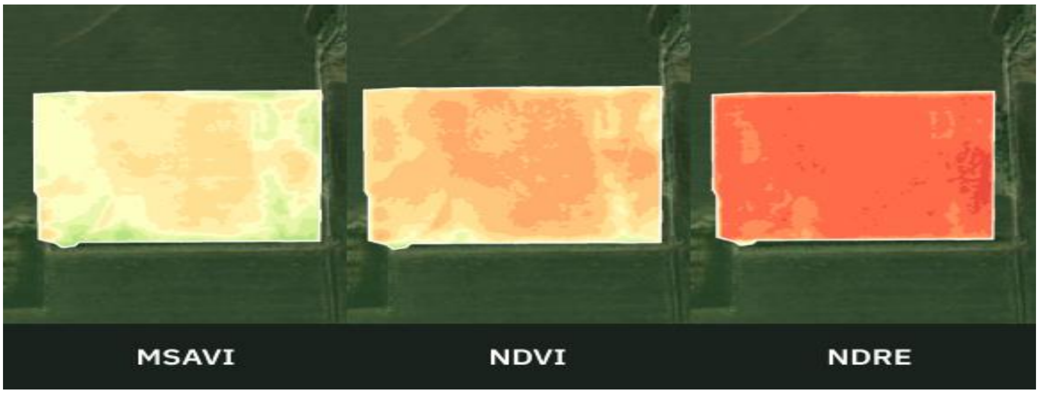

Fig. 3. How three different indices are effective in the early stage of crop development [18].

It could be necessary to fertilize low-yielding areas after the crop has been sown. The tools utilized may create a vegetation map based on MSAVI data (Figure 4). The season is the only variable that affects how these functions, otherwise it is identical to the NDVI-based maps. This will enable you to apply fertilizer at various rates according to the requirements of each agricultural region [17].

The NDRE index is specifically designed to highlight subtle differences in vegetation and is sensitive to changes in plant color and health, particularly in the red-edge region of the spectrum, which is often used in agricultural studies for detailed vegetation analysis. Using NDRE in agricultural remote sensing allows farmers to gain valuable information about plant health and identify potential problem areas such as water stress or nutritional deficiencies. NDRE images can be collected using drones or other remote sensing platforms and can be used in precision farming practices to optimize crop management (Figure 5) [18]. When the crop is fully grown and beginning to ripen is the ideal moment to use the normalized red edge difference index. Usually, this occurs as the growing season is concluding. Values below 0.6 in the mid- to late-season will almost probably indicate some kind of crop damage [19].

Since chlorophyll is necessary for photosynthesis, a plant's ability to produce it is largely dependent on its amount. For the NDRE index in crop monitoring, we employ a standard scale ranging from -1 to 1. [19]. From -1 to 0.2 indicates bare soil or a developing crop, from 0.2 to 0.6 can be interpreted as either an unhealthy plant or a crop that is not yet mature, from 0.6 to 1 are good values indicating a healthy, mature crop [19].

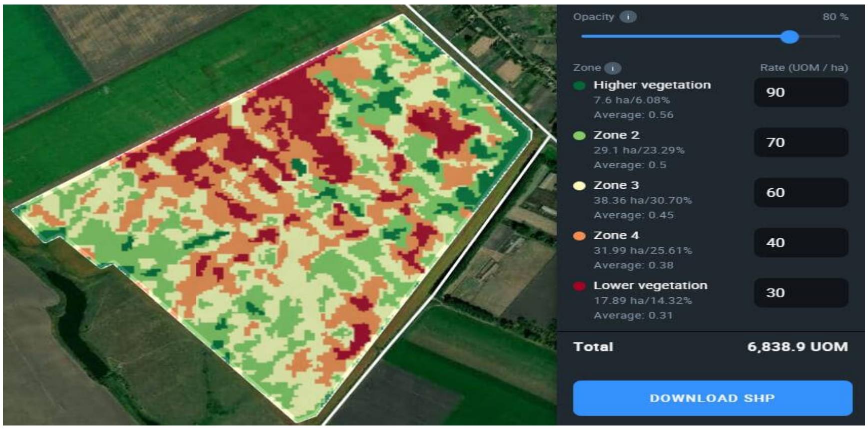

Fig. 4. Vegetation map based on MSAVI to apply VRF (variable fertilization rate) [18].

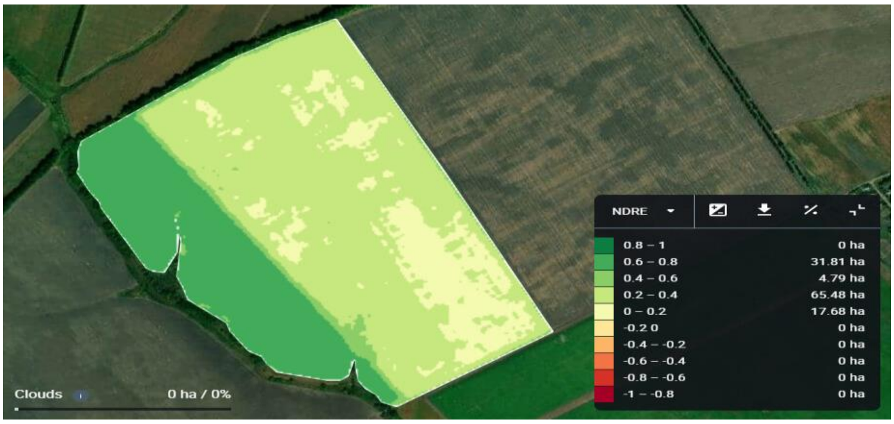

Fig. 5. NDRE map of some agricultural crops [18].

NDVI (Normalized Difference Vegetation Index) is a spectral index widely used in agricultural and ecological remote sensing to assess vegetation health and vigor, evaluate irrigation efficiency, identify areas of water stress or nutrient deficiencies, and for harvest planning and crop yield estimation. NDVI images can be collected using multispectral sensors mounted on drones, aircraft or satellites, providing a comprehensive and detailed view of the state of vegetation at the agricultural field level [19].

The chlorophyll element in a healthy plant absorbs most of the visible red light, while the plant's cell structure reflects most of the near-infrared light. This means that high photosynthetic activity, typically associated with dense vegetation, will have lower reflectance in the red band and higher reflectance in the near-infrared band shown in Figure 6. By observing how these values compare with each other, plant cover can be reliably detected and analyzed separately from other types of natural land cover [20].

Studies indicate that NDSI and MSAVI can be used for early diagnosis of plant development problems in different areas of fields. The use of these indices also allows the development of maps for differentiated fertilizer application in advance.

Fig. 6. NDVI vegetation index values [20].

4. CONCLUSIONS

By combining remote sensing technologies with precision agriculture, farmers can improve farm efficiency, reducing costs and environmental impact, while ensuring more sustainable agricultural production. The natural resource management and agricultural remote sensing both benefit greatly from the use of vegetation indices like NDVI (Normalized Difference Vegetation Index), MSAVI (Modified Soil-Adjusted Vegetation Index), and NDRE (Normalized Difference Red Edge). Utilizing these vegetation metrics has benefits [18]:

- Monitoring plant health - Vegetation indices such as NDVI, MSAVI and NDRE provide detailed information on plant health. These indices are sensitive to changes in chlorophyll content and photosynthetic activity, allowing farmers to quickly identify areas affected by disease, pests or other stresses;
- Water stress detection - Spectral indices can highlight areas of water stress in crops. Water-stressed areas may show changes in near-infrared reflectance, which can be detected by indices such as NDVI and NDRE;
- Optimizing resource management - Vegetation indices help to identify areas of different plant vigor. This information can be used to optimize the management of resources such as water, fertilizers and pesticides, tailoring them specifically to the needs of each area of the field;
- Crop yield estimation - Spectral indices are used to estimate crop yield by assessing plant density and health. This provides farmers with useful information for harvest planning and yield estimation;
- Soil zone identification - MSAVI is designed to reduce the influence of soil on vegetation assessments. This index can be useful in areas with variable soils, where soil reflectance can bias assessments obtained with other indices such as NDVI or NDRE;
- Monitoring changes over time - Vegetation index images can be used to monitor crop changes over time. This is useful in early detection of problems and real-time decision making based on up-to-date information.

In conclusion, the use of vegetation indices in agricultural remote sensing brings significant benefits, facilitating more efficient crop management and more sustainable use of agricultural resources.

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