Creating Fertilizer Application Map via Precision Agriculture Using Sentinel-2 Data in Uzbekistan

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Abstract. Precision farming requires detailed information about the field and the plots within it. Key information about the diversity of farmland characteristics is collected by taking and analysing soil samples to determine the optimal amounts of used seed, fertilizer and other substances, which can increase yields, reduce unproductive costs, and thereby achieve greater return on investment. From year to year, using spatial information and analysing a constantly updated knowledge base, the manufacturer consistently improves the results of his enterprise. Such technologies and solutions based on them of different levels and scales are suitable for all farms, and with a fully functional corporate-wide implementation, they are especially promising in large agricultural holdings with large the size of the fields and the high variability of the species composition of soils, their structure and fertility, susceptibility to damage to crops by diseases and pests. Geographic information systems serve as an essential integration component of precision farming solutions.

Keywords: Agriculture industry · Remote sensing · Farming · Fertilizer

1 Introduction

The geographical information system (GIS) and remote sensing (RS) technologies have great potential for analysing in the agriculture field [1]. RS and GIS have high potentials of improving precision-farming agriculture land mapping [2]. It represents and develops a unified process for managing agricultural land, the growth and productivity of crops in accordance with their needs and taking fertilizer of the crops [2, 3]. Precision Agriculture

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primarily involves the use of GIS and RS technology to map the spatial changes in crop and soil conditions of crops and their correlation with agricultural inputs such as water and fertilizer at a spatial basis [4]. Analysing of receiver data Sentinel-2 satellite system constitutes one of the most tested, designed and reliable satellite systems, even though the spatial resolution of 10 m that provides is not fully considered satisfactory for pixel to pixel comparison [4]. The task that any specialist working with data on arable land faces is to verify and ensure their accuracy. Creating electronic map based on the results of information comes from RS sources, for, digitization of aerial photographs and satellite images, scanned plans; Receive in real time or recreate based on archived data [5, 6]. With any of these options, and especially when used together, errors can occur, such as intersecting fields, mismatched borders, typos in the name of the crop, or simply unfilled characteristics of the objects. Remote Sensing allows correcting the errors found, as well as ensure high quality data with the subsequent introduction of additional information [1, 3].

Precision farming is an integrated high-tech agricultural management system that includes technologies for global positioning GIS technology for remote sensing of the Earth (ERS), technologies for assessing yields (Yield Monitor Technologies), technology for variable rate setting (Variable Rate Technology), and technology for geographic information systems (GIS) is an integrating basis for the accumulation, storage, processing, modelling, interpretation, analysis and display of all collected information characterizing crops, arable land and environmental factors, the entire agricultural landscape [5–7].

Often such guidelines are made for each operating area. Since the above data is known for each point in the field, the farmer can accurately calculate the required amount of applied substances at each point. Applying the exact dosage at each point, the farmer not only cares about the health of the crop, but also reduces his costs for agrochemicals and other material resources [8, 9].

The study area is the territory of agricultural lands of Tashkent province. These areas are clearly numbered agricultural areas. Spatial images of these areas were taken and analyzed (Fig. 1). Variable dosage recommendations are based on exact formulas and consider additional factors such as crop growth, water conditions, production, and soil type [10, 11].

To achieve additional increases in yield, the grower deliberately applies approximately of the substance in certain areas of the field to test the correct application rates of nutrients [12]. This technology became possible thanks to the development of informatics, communication systems, progress in the field of automation of agricultural machinery and equipment, the development of special sensors and measuring complexes for collecting information in the field [13], understanding how ecosystem work [6] and assessing the effects of future land use change on nutrients [9].

GIS and RS analysis of fields is give opportunity to increase machine capacity and obtain efficient fertilizing [14]. Important in any farm operation and may affect farm machinery is timeliness efficient fertilizing. Fertilizing map also key important of managing to complete a farm activity at such a time that crop return (quantity and quality) is optimized. Insufficient fertilizing mapping capacity may prevent completion of a field operation and create economic penalties [14, 15]. In some cases, the quality of

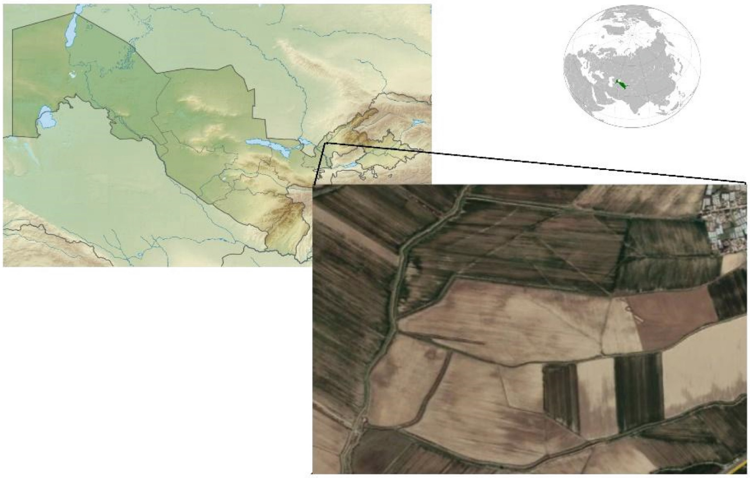

Fig. 1. Study area (*Source* GRID-Arendal and www.earthexplorer.usgs.gov).

field crops, including grains and hays, or horticultural crops, including vegetables and fruits are affected by the dates of planting and harvesting which represents a hidden cost associated with farm machinery [16]. RS data loggers can easily generate and store time and position information of field. RS data analysis and computer algorithms can provide managers with essential information for analyzing machine learning.

2 Materials and Methods

Normalized Difference Vegetation Index (NDVI) is one of the one of the latest used vegetation indexes and its utility in satellite assessment and monitoring of global vegetation cover has been well demonstrated over the past two decades [7].

Estimation of NDVI (1):

- General plant health condition
- Photosynthetic activity
- Possible deficiency of nutrients.

$$\text{NDVI} = (\text{Band 8} - \text{Band 4})/(\text{Band 8} + \text{Band 4}) \quad (1)$$

Band 8 = Near Infrared.
Band 4 = RED.

where Near Infrared and RED represent surface reflectances averaged over visible ($\lambda \sim 0.560\ \mu m$) and near infrared (Near Infrared) ($\lambda \sim 0.842\ \mu m$) regions of the spectrum, respectively.

The NDVI is correlated with certain biophysical properties of the vegetation canopy, such as leaf area index (LAI), fractional vegetation cover, vegetation condition, and biomass. NDVI gradually increases near-linearly with increasing Leaf Area Index (LAI) and then enters an asymptotic phase in which NDVI increases very slowly with increasing LAI [17, 18].

For the analysing downloaded all the available geo-rectified Sentinel-2 imagery less than 3% cloud cover for the study area. We added two L1G images acquired between April and October with less than 3% cloud cover. To evaluate (locate) the current situation in the field in the best possible way, the field was recorded during visit to the main local farms and their owners. Shorter surveys can be carried out in the process with farm owners. In addition to obtaining important technical data, this also provides an insight into the main issues in production. Also, each farm owner is required to submit a map showing the current situation and the location. These mostly include sketches or old plans that were either copied by hand or photocopied and thus diminished from the original cadastral maps. Maps very often include a legend on the field boundaries showing the types of crops grown, and each field has its own identification number [19]. Preparation of the thematic GIS layers in the process of preparing GIS layers, several raster resolutions are used:

(1) Basic resolution for calculation of suitability, 100 m;
(2) Sentinal-2 image at 10 and 10m resolution;
(3) A detailed topographic map 1:100 K, also at 10 m resolution.

For raster data we can use open source from internet source www.remotepixel.ca, for the NDVI analysis we need to download two raster images red (B4) and near infrared (B8). The work flow of the methodology was run as illustrated in Fig. 2.

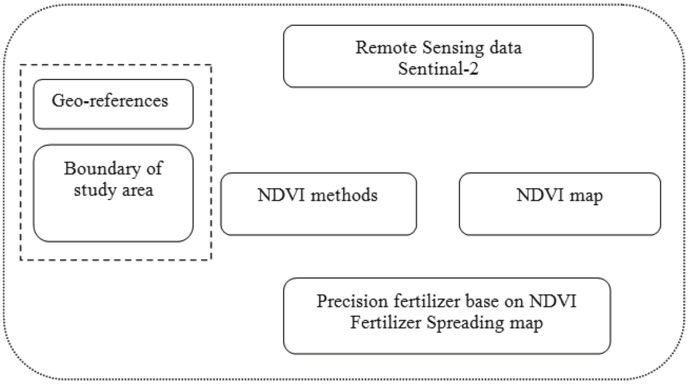

Fig. 2. Flow chart for adopted methodology.

3 Results and Discussion

Various vegetation indices are often used in precision farming, and the NDVI is the most popular one. It allows monitoring fields and crops at any point of the globe using satellite images. Here is a simple explanation of what the NDVI vegetation index is and how to use it for field analysis. It is important to understand that the NDVI is an indicator of the plant's health but it says nothing about the cause of a particular condition. The vegetation index is rather a hint at what is currently happening on the field. Let's consider three scenarios of NDVI usage for field analysis: at the beginning, in the middle, and at end of the growing season. At the beginning of the season, the NDVI index helps to understand how the plant has survived through the winter. If the NDVI is lower than 0.15, most probably all the plants died in this part of the field. Typically, these figures correspond to plowed soil without any vegetation. 0.15–0.2 is also a low value. This may indicate that plants started wintering in the early phenological phase, before tillering. Probably, the plants entered the tillering stage and have resumed vegetation (Fig. 3).

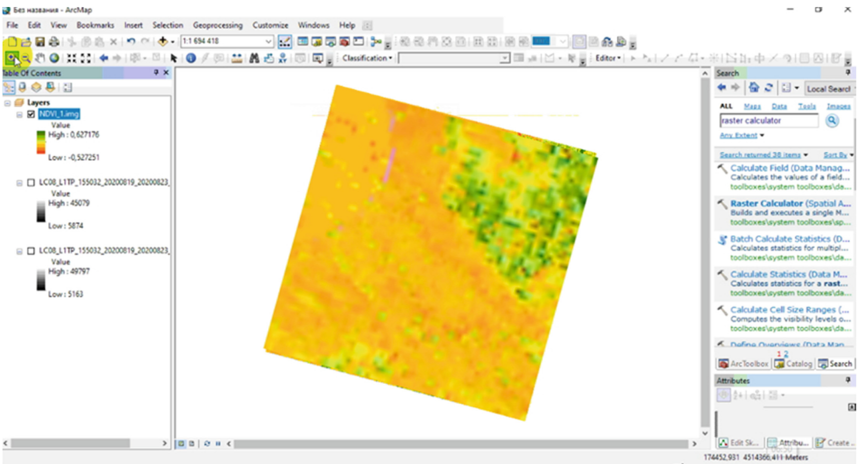

Fig. 3. NDVI analysing using ArcGIS software.

Nevertheless, it should be kept in mind that high NDVI values can indicate that plants wintered at a late phenological stage. If the satellite image was taken before the resuming of vegetation, then it is necessary to analyze the zone after the resuming of the vegetation also. Above 0.5 is an abnormal value for the post-wintering period. It is better to check this field zone. To sum up, if seen abnormal NDVI values (those that are very different from the average values for the field), it is needed to check this field area. It can be seen the NDVI index for r fields, monitor when the weather is cloudless, images are updated every 3–5 days. In results we get the maps identified in the traditional way and using NDVI analysis. In the traditional method, an equal amount of fertilizer is applied to all contours. Using a map identified and created using NDVI analysis, the exact coordinate fertilizer is applied and the crop is fertilized with as much fertilizer as needed (Fig. 4). This increases economic efficiency and increases soil fertility as well.

Traditional farmers measured crop yields for the entire field or large scales (Fig. 4). This measurement so called 'collect-and-weigh' method ignores variations in soil, and crop. With the fertilizer map based on NDVI analyse possible to measure yield on much smaller scales.

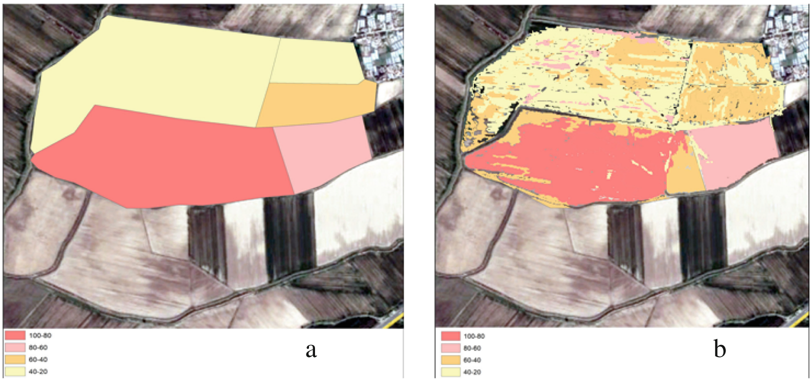

Fig. 4. Fertilizer application map: Standard fertilizing (a) and Precision fertilizing based on NDVI (b).

4 Conclusions

Using fertilizer map can be measured yield data can be georeferenced with coordinates of the corresponding yield data points using computer programs and create a database to create yield map. The yield map can be base map of machinery learning using GPS is the first step in precision analysis of farm machinery operation. Simultaneously, processing such data provides useful information about the field monitoring such a soil, crop.

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