

Development of Unmanned Aerial Vehicle for Crop Physiology Assessment and Site Specific Application of Pesticides

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ABSTRACT: Agriculture is one domain where technology still remains dull especially in India. With increasing demand for food supply, the assistance of technology in this domain has become a necessity. Various parts of the country have experienced crop damage due to disparate crop health issues which is extremely difficult to suspect from usual manual methods. The existing issues of crop damage make precision agriculture a necessary idea to explore. Precision agriculture is the methodology of crop monitoring using sensors in order to analyse the plant physiology and uplift the yield of the crops. Remote sensing technology has to take a huge leap with their multi-disciplinary applications using UAVs. This work proposes the idea of using multispectral camera that provides good spectral and spatial resolution images which can be mosaicked to prepare ortho-images. The ortho-images can furthermore be used to create the NDVI map which can be extensively used to emboss the diseased or pest affected areas. The entire flight is optimized and controlled by the flight controller which allows the quadcopter flight to be completely autonomous. After analysing the NDVI maps, which clearly highlights the affected area, the pesticide operation can be commenced by changing the flight path to the desired location. The quadcopter can swiftly spray pesticides on the affected areas and return to the take-off position. In this paper we have emphasised on precision agriculture by analysing the crop physiology through airborne multispectral imaging and pesticide spraying on the affected areas.

KEYWORDS: UAV, NDVI, physiology, mission planning, ortho-photos, pesticide.

I. INTRODUCTION

Unmanned aerial vehicle (UAV) or unmanned aerial system (UAS) is a system that contains various subsystems that includes the aircraft, its payload, communication and navigation subsystem, support subsystems, aircraft launch and recovery subsystem, subsystem involving its application etc. UAVs have increasingly been used for various civilian and military purposes due to recent advances in technology in this domain [1]. Unmanned aerial vehicles are being used extensively for precision agriculture, inspection and surveillance and aerial imagery [2]. Variety of UAVs are being constructed and used now-days which can be characterised as stated in **Table -1**.

Table -1 Classification of UAV

HALE	High altitude long endurance	Ceiling: 15000 m and 24 hour + endurance; used for military purposes
MALE	Medium altitude long endurance	Ceiling: 500-15000 m and 24 hour endurance; used for military purposes
TUAV	Tactical UAV	Range: 100-300 km; used for various land and naval services
Close-Range		Range: < 100 km; used for surveillance, agriculture, military, security inspections
MUAV	Mini UAV	Range up to 30 km, mass: < 20 kg; used for

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		various civilian applications
MAV	Micro UAV	Wing span: <150 mm; used for civilian indoor operations
NAV	Nano air vehicle	Extremely small size, can be used for short range surveillance provided subsystems can be designed small enough
RPH / VTUAV	Remotely piloted helicopter/ Vertical take-off UAV	UAVs with the ability to take-off and land vertically; less subsection to turbulence
UCAV / UCAR	Unmanned combat rotorcraft/ Unmanned combat rotorcraft	UAVs that can be used for launching weapons and can be used for combat applications

One of the most appreciated civil applications of UAV is for precision agriculture. Precision agriculture is a management methodology wherein the crops are closely inspected for various parameters, observed and analysed and reacted as per the results concluded. UAVs paired up with remote sensors have declared to be a vital asset in the field of precision agriculture that provides low cost and accurate analytical solutions. Remote sensing, which was primarily done by remote sensors on towers above the farm fields or by satellite imagery have not been satisfactory in providing accurate spatial and spectral data. UAV based Remote sensing technology is extensively used to record images at low altitude that can be used to make vegetation indices maps and weed control maps. UAVs equipped with cameras and image processing units have also been used for finding crop height, water stressed regions in the farm and comparing crop growth [4]. Precise results of the analyses can be achieved by good spatial and spectral resolution of the images recorded by the cameras, thereby making it a necessity. However, resolution range depends on the application of the drone as spatial resolution for biomass and yield application is 1-3m and that for weed control purposes is 0.5-1m. The aim of this paper is to present a methodology for development of an unmanned aerial vehicle (UAV) that is useful for performing detection of crop health and spraying pesticides on the affected areas respectively.

II. LITERATURE SURVEY: REMOTE SENSING OPPORTUNITIES IN AIRBORNE SYSTEMS

Remote sensing technologies have been booming in the recent past, especially via airborne media. Various UAV platforms with disparate cameras and sensors pertaining wide range of spatial and spectral resolution are used for this operation. The analyses of the image is basically concentrated on particular leaves and canopies' wavelength reflectance in visible range (red, green, blue), non-visible as IR (Infra-red) and the emission of far- infrared (thermal). Recently many efforts have been made for sensing fluorescence of chlorophyll as more effective approximation of electron transfer rate (ETR) and gross primary production.

SENSING LEAF/ CANOPY REFLECTANCE

Leaf reflectance is an effective indicator of plant's functions because the light reflected from the leaf is directly correlated to the leaf's pigment composition, which can therefore be used for analysing the plant's physiological condition. Vegetation Indices are primarily extracted from RGB and IR, and other wavelengths of the spectra. The most widely used index is NDVI or normalized difference vegetation index is an index calculated for visible and infrared light which is reflected by the plants, once sunlight falls on them. The chlorophyll present in the plants absorbs the visible light and the leaf structure or primarily the cells, reflects the infra-red spectrum. The NDVI can have range from -1 to +1 in which healthy crops are categorized with the values closer to +1 (0.8-0.9). A zero value of NDVI signifies no vegetation, in accessed area. This index is commonly used to detect plants and the "greenness", due to the embossed IR reflectance of chlorophyll, which is directly connected to the plant physical and physiological factors. It was originally used for inferring the area covered by the vegetation in fields by the satellites [4]. The equation used for determining NDVI is:

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$$NDVI = \frac{R_{NIR} - R_{Red}}{R_{NIR} + R_{Red}} \tag{1}$$

where R_{NIR} , R_{Red} is reflectance in NIR and red bands, respectively. NDVI index result is a dimensionless value, ranging between -1 and 1. There have been works done by various research groups [3,5] that have focussed on generating NDVI using visible, infrared or multispectral cameras on board an unmanned aerial vehicle and has shown appreciable results in monitoring crop health [4].

III. SYSTEM DESCRIPTION

UAV PLATFORM

The UAV platform which was used for this particular application is a quadcopter. UAV system is an elegant system comprising of interlinking of multiple subsystems that run in parallel or serial manner to serve its operation. The auto-pilot module used in the UAV is APM 2.6 or Ardupilot mega which uses 3DR GPS uBlox LEA-6 which is paired with compass module for full autonomy. The GPS/compass module can be mounted away from noise sources than the APM itself in order to avoid attenuation of the GPS signals. The ground station gets the telemetry data from the quadcopter. The auto pilot is fed with the data from the ground station that defines the flight path of the copter, enabling various missions like waypoint navigation. The auto pilot allows making changes in waypoints, mode and even the values of control parameter using two-way wireless connection, which can be performed by the ground station. This extensive feature of the auto-pilot allows in-flight mission planning, which acts as a boon for optimised copter application. The interconnection of major systems can be shown in Fig. 1 (a).

The flight controller used is auto-pilot mega (APM) which is a user friendly platform, used for various commercial or industrial usages. Few vital features of the system are:

- Flexible in flight path as the UAV can be pre-programmed for a flight path for any area.
- Automatic take-off, followed by automated pre-programmed path follower
- Flexibility in terms of changing flight path, in flight

The overall system and subsystems connections can be observed in Fig. 1 (b).

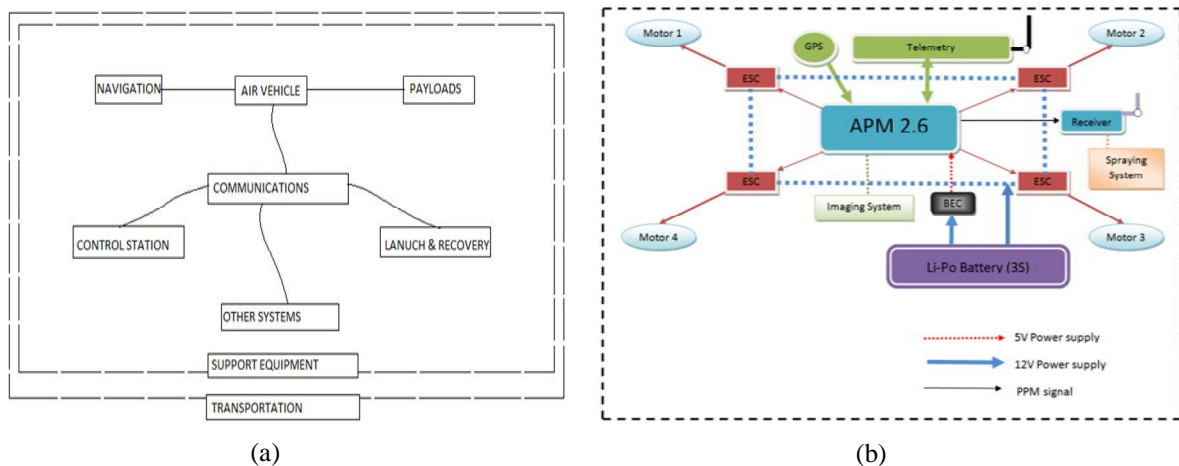


Fig. 1. (a) & (b) System Overview with specification of system and subsystems

The specifications of the quadcopter can be inferred from **Table -2**. It includes system specifications and flight operational parameters.

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Table -2 Specifications of the UAV

Type	Multicopter
Diameter	450mm
Empty weight + Battery	900g
Max all up weight	3kg
Payload capacity	2kg
Voltage	11.1V (3S)
Battery capacity	3500mAh, 30C
Max operation altitude	200ft
Flying time	20mins
Fail safe function	RTL, Auto land, system override
Auto take off	Yes
Maximum speed	6 meter / sec

SUBSYSTEM

The quad copter will be used for furthermore improvisation by addition of two subsystems, namely: Imaging subsystem and spraying subsystem that will perform indigenous tasks of mapping and spraying respectively. The subsystems of the UAV are modular based in order to perform bi-functional operation: imaging and spraying respectively. Due to lack of well-defined rules and regulations on the implementation on these sophisticated systems on UAV and its operation in civilian grounds, the subsystem implementation was not performed. However, the proof of concept for all processes can be witnessed in the paper, furthermore.

The information regarding the subsystems can be referred below:

IMAGING SOLUTION

The imaging solution suggested for this application is a multispectral camera TETRACAM ADC Lite which weighs 200 grams, is a powerful sensor is remarkably compact. This camera has four narrow band filters optimized for analysing crop health. It has a CMOS sensor with the resolution of 3.2 megapixels. The red, green, and IR bands provide information required for mapping NDVI, SAVI and green/NIR ratios. The camera has a high photo rate which makes it a vital choice for precision agriculture. The camera is optimized for capturing visible light wavelength longer than 520 nm and near-infrared wavelength up to 920 nm (resolution).The recorded images are retrieved from the internal storage of the camera and are stitched together for data processing and analyses. The images are mosaicked together to form a single image from the array of all the images collected. Good resolution mosaicked images are essential for farmers which can be used for analysing opulent plant health factors like, water stress, pest infestation, weed growth. The efficiency of the mosaicking depends on the calibration of camera and percentage of overlapping of the images. In our work, we used Pix4Dmapper Pro mosaicking software, open source software which performs good mosaicking operation.

The images from the sensors are captured with the additional information which vital for determining the position of the damaged or disease struck part of the farm field. The GPS sends the additional information which is stored with the images, is geographical location of the image taken and the precise time of capturing the image. The visible camera receives signals for triggering from the auto-pilot system of the UAV. The triggering process of the camera stores the recorded images in the internal storage memory of the camera. The imaging subsystem can be summarized as shown in Fig. 2 (a).

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SPRAYING MECHANISM

Spraying subsystem primarily performs the function of spraying pesticide or fertilizers on the crop field of the affected areas that can be analysed by the information acquired by the cameras the spraying mechanism constitutes various components. This mechanism forms an extensive setup that can be installed on the UAV platform once the images are analysed. The PWM values are fed by the receiver that in turn controls the speed of the motor pump. The fluid is withdrawn from the chemical tank, which passes through the pump towards the nozzle. The fluid from the tank is pumped and fed to the nozzle. The fluid is sprayed onto the crops effectively in a pre-defined and site-specific flight path, making the entire process of pesticide spraying hassle-free and immaculate. The spraying system can be summarized as shown in Fig. 2 (b).

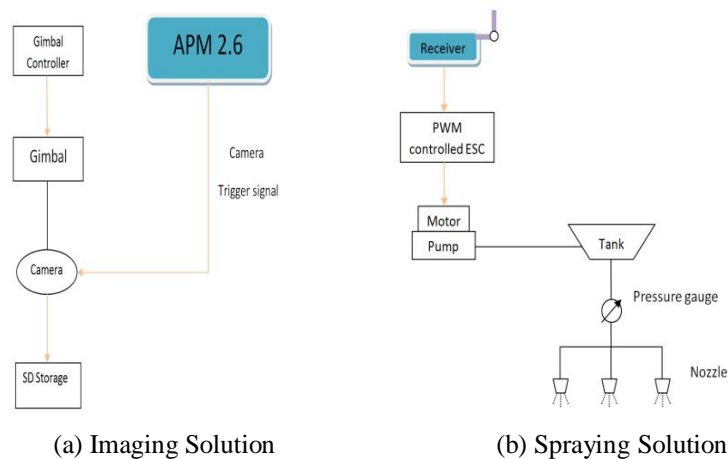


Fig. 2. (a) shows the imaging subsystem specification and (b) shows the spraying subsystem specification respectively

The proposed specification of the component of the spraying mechanism can be referred from **Table -3**.

Table -3Proposed specification of spraying system

COMPONENT	FUNCTION	SPECIFICATION
Nozzle	Evaluates flow rate	Material: high quality plastic and rubber Mist particles: ≤ 70 microns Flow rate: 6 litres/hour Spray diameter: 0.8 m
Chemical tank	Stores the pesticide	Dimension: 210 x 110x 100 mm Material: polyurethane
DC pump	Pumps liquid from tank to the nozzle	RS 360mini DC (4- 12 Volts) Current: 0.8A Weight: 70 gram

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IV. WORKING OF THE UAV FOR PRECISION AGRICULTURE

MISSION PLANNING

The system was tested over the fields of rural Bangalore with a coverage area of 1 acre. The UAV was flown at 200 ft. altitude, making sure the entire area of focus is easily covered. The flight was completely autonomous and the flight path was pre-fed to the airborne system by Mission Planner. The data points were fed to the Mission Planning software that provided a well-defined path for the quadcopter to follow. The first stage of the mission was completed by flying the UAV over the field on pre-defined flight path, which was monitored by the flight controller. Fig. 5. shows the mission planning stage wherein the way points are specified for prescription of flight path.

IMAGING AND MOSAICKING

As stated earlier, that analysis of the field via multispectral images was not possible, however for proving the concept of mosaicking, we took RGB image from GoPro camera that recorded the images with spatial resolution of 12 megapixels. The endurance of the UAV was 25 min. However, the entire field can be covered in less time by increasing the ceiling, but this could be disadvantageous due to the reason of decreased spatial resolution. The recorded images were the stitched together by the software, Pix4Dmapper Pro which created the ortho-images of appreciable resolution. Once the images were mosaicked, various vegetation indices (like normalized difference vegetation index (NDVI), simple ratio index (SRI), crop water stress index (CWSI)) could be generated that can be used for analysing the crop physiology effectively. Fig. 6. illustrates the mosaicking of the images which were captured by quadcopter.

PROOF OF CONCEPT: NDVI ANALYSIS

As the images were RGB banded, NDVI formulation could not be implemented, as multispectral image is must for its extraction. In order to prove the concept of NDVI from multispectral images, we retrieved a multispectral image from www.tnris.org. which was used for the analysis. The image can be seen in Fig. 3. Among these, NDVI was used to create vegetation map that was used to infer the disease affected area in the farm field. NDVI vegetation map is a vital source of information which gives precise results with good resolution images. The analyses, made after reading the vegetation maps, were the basis for second stage of the mission.

The NDVI map is generated using the software arc map10.4.1 which gives precise map layouts in a user friendly manner. Arc map 10.4.1 is open source software which can efficiently produce NDVI maps with precise results. The captured images, stored in the storage device of the camera are uploaded in the software and NDVI maps can easily be generated with few simple steps. This image shows the NDVI generated for the mosaicked image over the farm field. Figure 7 and 8 shows the NDVI map for the image.



Fig.3. Multispectral image from [tnris.org](http://www.tnris.org), which was used to prove the concept

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SPRAYING

After analysing the NDVI map, the affected area can be accessed and treated via site-specific application of pesticides. 'Site-specific' feature can be implemented by mission planning wherein the quadcopter can be sent directly to affected area, spray pesticides and return to the workstation. This allows optimisation of pesticides usage and application.

V. EXPERIMENTAL RESULTS

This section shows the experimental results that were obtained from different stages in the research. Fig. 4 shows the quadcopter system with APM 2.6 or Ardupilot mega which is using 3DR GPS uBlox LEA-6. Fig. 5, shows the way point navigation above the required area. This prescribes the flight path for the quadcopter to fly autonomously. In the initial and final path lines the camera is tilted at certain angle to capture a 3D view of the area. The images captured by the camera were procured and processed to stitch the images to make one continuous image of required area. Mosaicking process can be seen in Fig. 6. In order to prove the concept, a multi-spectral image was used to prepare NDVI map. Fig. 7. and 8. shows the NDVI map and its value at a particular area.

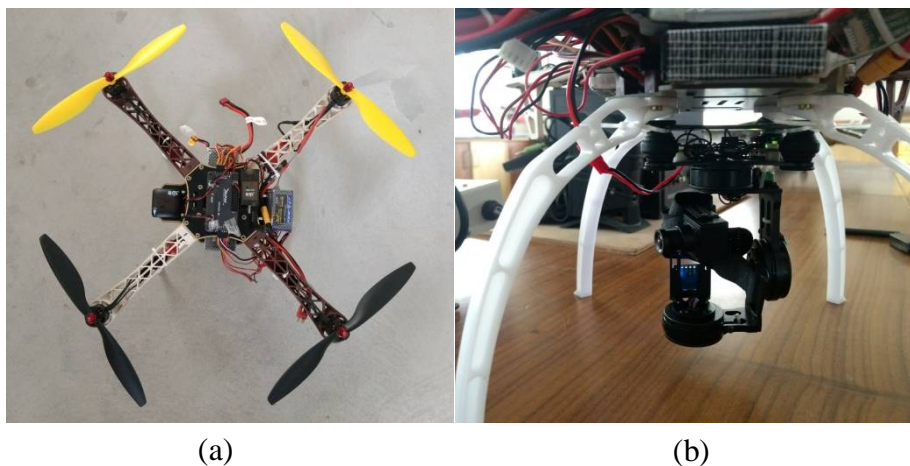


Fig. 4 (a) & (b). The quadcopter images with the specifications described above in the paper.

The image shows the quadcopter system with APM 2.6 or Ardupilot mega which is using 3DR GPS uBlox LEA-6. It also shows gimbal with camera mounted on it. The telemetry is used to monitor and navigate the quadcopter. It also feeds the changes in way point path.

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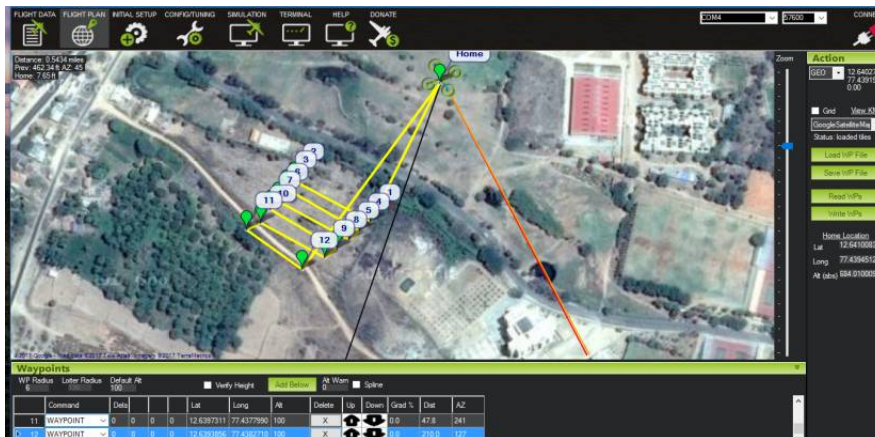


Fig. 5. The image shows way point navigation to capture images of a particular area.

This was performed during mission planning stage. The flight path was prescribed initially, which was followed by the quadcopter. The entire flight of the UAV was autonomous. The quadcopter completed its flight path from way point no. 1 to 12, finally returns back to its launched point from where it was deployed (Home).

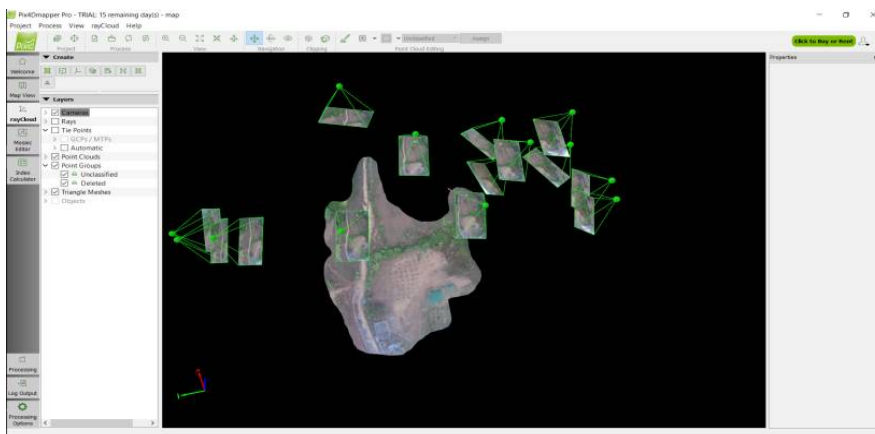


Fig. 6. All the images collected by the RGB camera were extracted in the computer.

The procured images were processed to stitch into one continuous image of the required area. All the images are stitched carefully, maintaining the clarity of the image. The mosaicking was performed on Pix4Dmapper Pro software.

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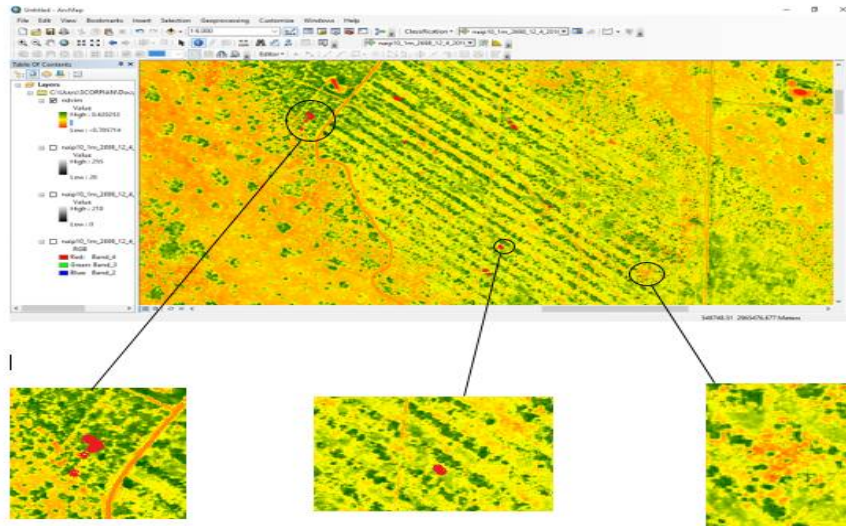


Fig. 7. The image shows the proof of concept of image processing wherein NDVI map is generated.

The software used for NDVI map generation is Arc map10.4.1. The zoomed images of the NDVI map generated can be seen, that can clearly highlight the affected or disease struck areas. The farm field was observed to be struck by disease in fragments of its area

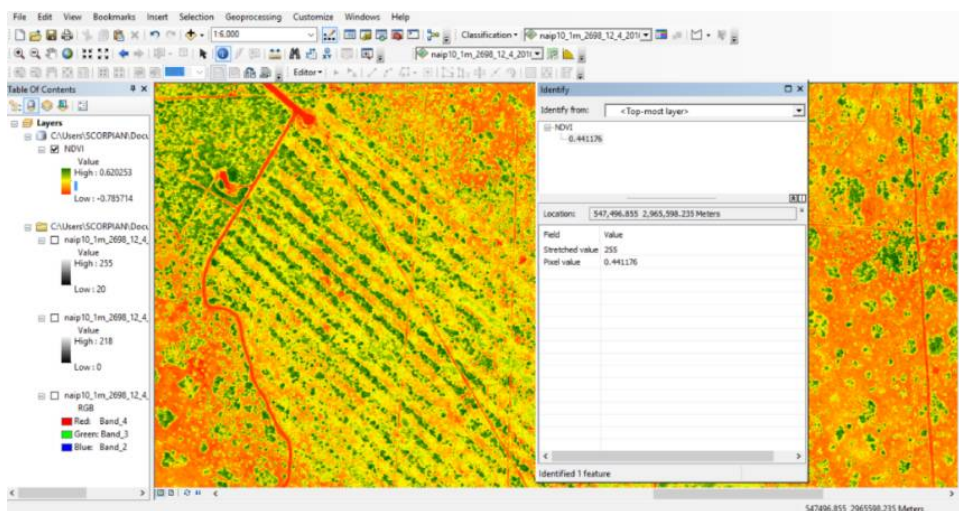


Fig. 8. The image shows the NDVI map indicating NDVI value of a particular location.

The value of the particular area in the image is calculated to be 0.44. The NDVI count of the less green patches on the map can be extracted and finally the unhealthy crops can be found.

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VI. FUTURE SCOPE

In the future as the rules for easy and constructive usage of UAVs for civilian purposes, especially for agriculture strengthens, we would indulge in the in-depth analysis of local farms via multispectral camera. In order to promote precision agriculture's vital aspect: site specific farming, the UAV will be used for spraying onto the affected zone of the crop field only. The spraying mechanism can be installed on the same plate where the cameras are mounted, which is detachable. The spraying setup which includes all the components as described above, are mounted on the UAV with the desired amount of pesticide which has to be sprayed on the crops. The site specific analysis is advantageous for various reasons like less wastage of pesticides, optimised usage of pesticide that reduces health hazards and other monetary advantages to the farmers.

VII. CONCLUSION

In this paper, we depicted an effective method to increase the crop yield by presenting multi-feature system capable of determining unhealthy crop and spraying of the pesticide efficiently. We performed airborne imagery over the fields and proof of concept of analysing the crop health by determining the NDVI map. The NDVI map showed clear images of the affected areas in the software as mentioned earlier. The software also provided NDVI score which made the analysis easier. After the inspection it was proposed that the UAV can be deployed to the specific area of interest (disease struck area; highlighted in the NDVI map) for efficient and precise spraying. Both the stages of the mission: imaging and spraying can be pre-programmed and controlled by the flight controller that performed the entire flight autonomously, thereby promoting precision agriculture. However, this proof of concept displayed convincing results in terms of analysing the fields using airborne technology; furthermore improvements in experimentation can be done.

REFERENCES

- [1]. J. Gago, C. Douthe, R.E. Coopman, P.P. Gallego, M. Ribas-Carbo, J. Flexas, J. Escalona and H. Medrano, "UAVs challenge to assess water stress for sustainable agriculture", *Agricultural Water Management*, Vol. 153, Issue No. C, pp. 9, 2015
- [2]. Lucas P. Behnck, Dionisio Doering, Carlos Eduardo Pereira, Achim Rettberg, "A Modified Simulated Annealing Algorithm for UAVs Path Planning", In *Proceedings of International Federation of Automatic Control*, Vol. 48, Issue No. 10, pp. 63, 2015
- [3]. Matthew Joordens, Tom A. Brodie, Thomas P. Oberli, Phil Swinsburg, "Conceptual Design for Fully Autonomous Aerial and Ground System for Precision Agriculture", In *Proceedings of 10th System of Systems Engineering Conference*, pp. 99, 2015
- [4]. V. Lukas, J. Novák, L. Neudert, I. Svobodova, F. Rodriguez-Moreno, M. Edrees, and J. Kren, "The combination of UAV survey and Landsat imagery for monitoring of crop vigor in precision agriculture", In *Proceedings of Int. Arch. Photogramm. Remote Sens.*, Vol. XLI-B8, pp. 954, 2016
- [5]. Jere Kaivosoja, Liisa Pesonen, Jouko Kleemola, Ilkka Pölönen, Heikki Salo, Eija Honkavaara, Heikki Saari, Jussi Mäkynen, Ari Rajala, "A case study of a precision fertilizer application task generation for wheat based on classified hyperspectral data from UAV combined with farm history data", In *Proceedings of SPIE*, Vol. 8887, pp. 1, 2015