Evaluation and Implementation of Precision Agriculture using Unmanned Aerial System

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Abstract: - In the present scenario farmers are spraying the fertilizer and pesticides to the entire farm, since precisely identifying and classifying the unhealthy plant is tedious. The proposed research addresses the problem utilizing Unmanned Aerial System (UAS) based multispectral mapping and localization method of Precision Agriculture. This method helps to identify the unhealthy plants and initiate localized spraying of fertilizer. Multispectral map of the Tea estate is constructed and stressed plants are accurately identified using Normalized Difference Vegetation Index (NDVI) analyses and the location is Geo-tagged. These locations were taken as a reference point for spraying, thus ensuring optimized utilization of fertilizers and pesticides. The tea plants cultivated using this method are claimed as organic grade. The proposed methodology will make crop protection economical and enhance the profit margin.

Key-Words: - Unmanned Aerial system(UAS), Multispectral Mapping, Normalized Difference Vegetation Index (NDVI), Geo-tagged, Crop protection, fertilizer spraying.

1 Introduction

Precision farming is defined as the information and technology-based farm management system to identify, analyze and manage variability within fields for optimum profitability, sustainability and protection of land resource [12]. Recently, Unmanned Aerial Vehicles (UAV) are deployed into the agricultural sector, for improving the productivity. Agricultural drones are used for soil and field analysis, planting, crop spraying, irrigation, health assessment and fertilizer/pesticides spraying. The current work focuses on crop monitoring, health assessment and spraying of fertilizers or pesticides by the use of UAV. It aims for covering a farming field of about 5 sq.km and to acquire highly accurate images in a single flight. Unmanned Aerial Systems (UAS) is an emerging technology, which proves to be more economical than the present satellite technology.

Tea is an indigenous product and India stands as the second largest producer of tea in the world. In all aspects of tea production, consumption and export, India has emerged to be the world leader, mainly because it accounts for 31% of global production. It is perhaps the only industry where India has retained its leadership over the last 150 years. According to ASSOCHAM report, India continues to be the world's largest producer and consumer of tea and has over 13,000 tea estates with a combined area of about 563.98 thousand hectares, of which 70% are distributed in Northeast India. The turnover for tea industry in the last financial year accounts to about 44170.11 million.

Tea yield statistics show that tea plants start to produce tea leaves from their third year onwards (approximately) and maintain a steady increasing trend up to some 50 to 100 years of age (Wild plant till 1700 years). In their lifespan, they reach a peak production value for a span of years and decline. Once in every three weeks, the farmers classify the tea leaves into different grades - A, B, C (i.e. Green, black, white tea respectively). These grades are attained by varying the levels of oxidation. The plucking season begins early in May and ends in late November or early December. This show that the highest yield is during the month of July and august when rainfall is heavy. At the end of the plucking season, the bushes are pruned by 6 to 15 inches and is left to grow for the next three months.

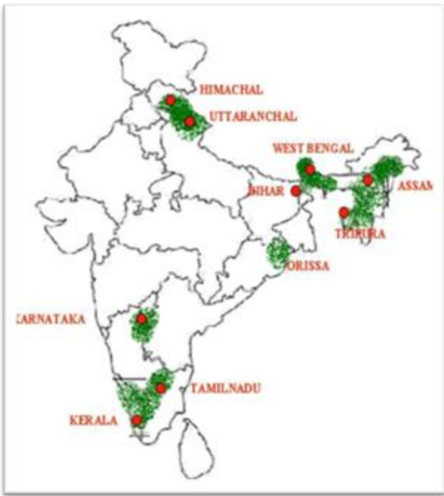


Fig.1. Map showing plantation in India

2 Problems faced by Tea Industry

It is observed that tea production is affected by many factors such as old plantations, declining soil health, water logging, increasing threats of pests and diseases etc. The leaves which smut during the winter season are cleaned, every three to four years, and the trees are cut to half their height. Red spiders create major problem for the plants during summer season. Mostly Zn-Mg chemical composition is provided for a healthy tea bush and Ammonia + TAP (powder) in month of April and Urea is used during the month of June and July to grow into healthy tea plantation. Some of the symptoms that are experienced by an unhealthy plant are [3]:

- Algal leaf spot
- Brown blight, grey blight
- Blister blight
- Horse hair blight
- Twig dieback, stem canker

The amount of chlorophyll content and structure would vary in an unhealthy plant compared to healthy plant, which affects the NDVI signatures. The World Health Organization (WHO) estimates more than one lakh deaths in each year, especially in developing countries, due to the fertilizers and pesticides sprayed by human being [1].

- Pesticide spraying creates health hazards including allergy, nerves system disorder, brain tumour, asthma, hypersensitivity, hormone interruption and cancer.
- The difficulties in the utilization of manpower, spraying cost and time consumption are the other significant problems.

The production and crop protection with precision agriculture methods using UAS embedded with multispectral camera looks promising in overcoming the above problems. With this, it is also expected that the use of pesticides is limited to only the affected area and thereby increasing profit margin.

The main objective of the paper is to evaluate and implement precision agriculture using UAS (Multispectral mapping and Chemical spraying). The work also aims at:

- Identifying the stressed plant using NDVI created from multispectral geo-tagged location.
- Optimizing the utility of fertilizers and pesticides.
- Spraying the chemicals to geo-tagged locations.
- Cultivate organic tea.

3 Systems Setup

In wide scale farming, it is difficult to control the condition and quality of the plantation area. Qualitative assessment of plant health is often based on the condition of the leaves. Agronomical researchers and companies are searching for new methods and procedures to help farmer to manage and improve the agriculture quality. Based on these backgrounds, this project presents a new method of UAV-based multispectral aerial images analysis for agricultural areas. UAVs are rapidly upcoming method for cultivation, production, protection processes and its operated remotely either by telemetry, where the operator maintains visual contact with the aircraft or autonomously along preprogramed paths using GPS and inertial guidance. Quadcopter was chosen for this project because of its high stability and lifting power and the control of quadcopter is easier than the helicopters. Quadcopters are also cost-effective alternatives to high cost standard rotorcrafts.

UAV developed at MIT under Tamilnadu innovative initiative scheme for multispectral image capture and sprayer model is used. The specifications of the model are as follows:

Table 1. Characteristics of the UAV Model

Specification – X8 Rotor Model	
Model Name	X8 Rotor
Weight without payload	4 kg
Payload weight	150 g
Gross take-off weight	4.15 kg
Maximum flying height	300 - 400 m
Normal Flight Time	35 minutes
Data Radio range	2.5 km
Frequency	2.4 GHz
Speed	30 - 60 km/hr
Structure	Carbon fiber and composite material
Autopilot	Opensource

Table 2. Characteristics of the Sprayer Model

Specifications – Sprayer Model	
Model name	AK – 61
Endurance	10 – 15 minutes
Cruising speed	5 – 10 m/s
Take-off weight	22 kg
Payload	10 kg
Maximum flying height	0.5 – 5 m
Tank capacity	10 liters
Working Temperature	-15°C to 50°C
Nozzle type	Pressure Nozzle
Spray range	4 – 6 m
Recommended Battery	2*1200 mAh Li-Po Battery

3.1 Quadcopter

An octocopter is an eight-rotor vertical take-off and landing vehicle that has the maneuvering abilities of traditional helicopters with significantly lower mechanical complexity. This low complexity increases the dependability while reducing the cost of manufacturing, operation, and maintenance. This kind of helicopter tries to reach a stable hovering and flight, using the equilibrium forces produced by four rotors. Quadrotors are therefore becoming a promising option for various unmanned military and civilian applications. Characteristics of X8 octocopter model UAV are presented in Table 1.

Fig.2. Top view of X8 Octocopter

Fig.3. Bottom view of X8 with payload

An X8 rotor uses eight motors, its mounted-on fours arms X shaped frame with four sets of CCW (Counter Clockwise) and CW (Clockwise) propellers. Figure 4 indicates the rotation of the above stated rotors. The prime advantage of using a redundant UAV model is that, failure of a single rotor will not affect the stability of the flight, and the flight could be landed safely. However, this type of type of UAV presents a weight and energy consumption augmentation due to the extra motors. Figure 5 is a ground power supply multi rotor tethered UAV rotor. It has an easily detachable arm with a plurality of nozzle for continuous spraying accurately without any damage to the crops. It also reduces the payload of UAV (decrease the time of refilling liquids) and maintain a constant pressure. On other hand it contains a power supply system to increase the endurance of UAV.

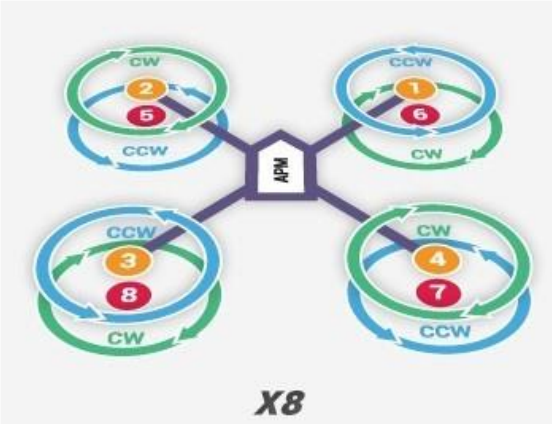


Fig.4. Motion of the Rotors

Fig.5. UAV Sprayer model

4 Mapping Workflow

Drone mapping helps us to extract information regarding a specific area, which is to be surveyed. The mapping workflow is a step by step procedure.

- Map design and flight planning
- Image acquisition
- Image processing
- Preparation and visualization of geo-spatial products
- Extraction of essential information

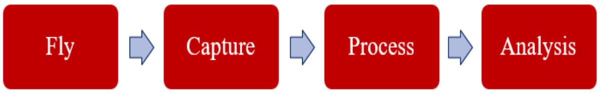


Fig.6. Workflow pattern

4.1 Map Designing and Flight planning

The study area is located in Ooty-Connoor, Nilgiris district, Tamil Nadu. The total size of the study area was 0.1153 sq.km and the image ground resolution was 0.065m, and timer mode was set at 60 m altitude. Multispectral image capturing technique is used by the drone during the Image Acquisition phase. Five band (Blue, green, red, red edge, near infrared) multi-spectral mica sense camera (Figure 7), designed especially for the precision agriculture is used. It is lightweight (150 to 180g), optimized for use in small UAS and available on manned aircraft as well. The main feature of this camera is that it simultaneously can capture five discrete spectral bands optimized for crop health data gathering. Moreover, all the bands are captured once per second, enabling faster flight.

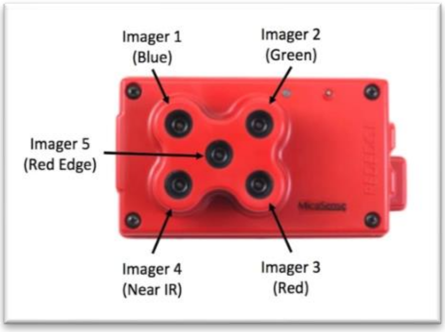


Fig.7. Mica sense camera

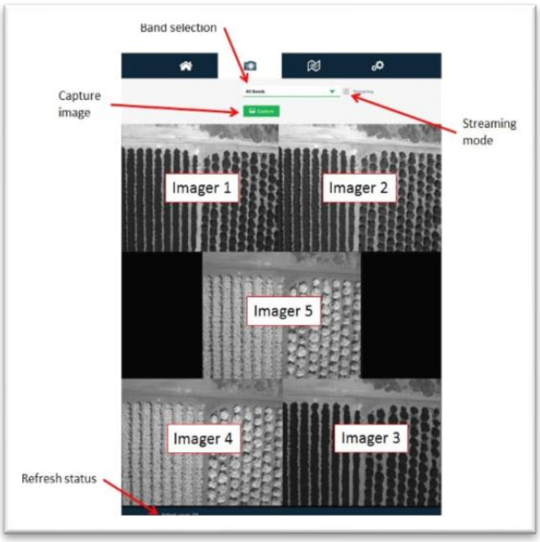
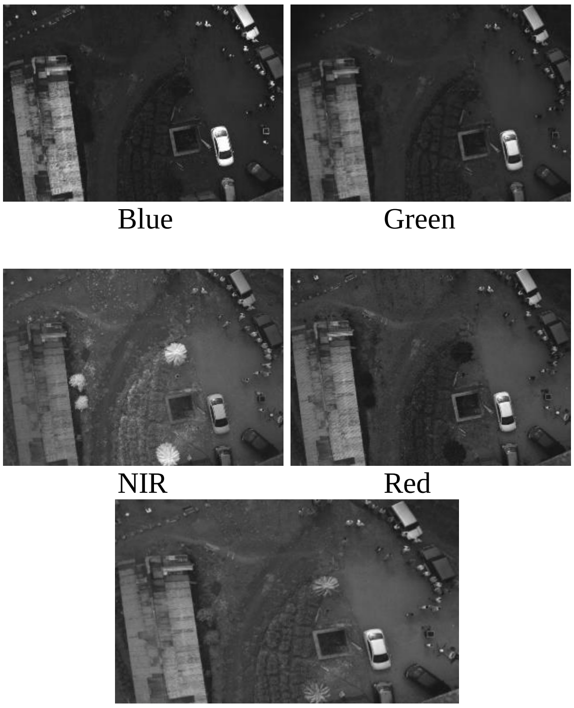


Fig.8. Samples of the captured images

4.2 Image Acquisition

Five spectral band images were the raw data received from the mica sense multispectral camera. The Orthomosaics obtained for Blue, Green, Red, red-edge and Near infrared spectral images are as follows.



Red Edge

Fig.9. Images of the Spectral Band

4.3 Image Processing

The multispectral images are captured by use of unmanned aerial systems(UAS) and then imported to an image processing software. The software used are Agisoft, pix4d cloud, global mapper, precision mapper. Agis soft is the software developed by Agisoft LLC is used by many Archaeologists and UAS to convert the multispectral image into Ortho mosaic and this output is imported into Global mapper to get NDVI maps. Pix4Dag along with Pix4D cloud will convert multispectral images into accurate index maps like NDVI. Pix4D cloud processes locally and can avail automated processing templates for Agriculture maps, which will reduce the workload.

Figure 11 is a visible image. The multispectral image consists of three primary colours (Red, Green, Blue). Ortho mosaics represents the perfectly scaled and stitched images of all the 700 images received and imported for use of Agisoft software.

Fig. 10. Satellite Image

Fig.11. Visible Image

Figure 12 shows FCC refers to the display of images in colour which will help to identify the visible and non-visible parts of electromagnetic spectrum. The Agisoft output was imported into the Global mapper from which the FCC images was processed.

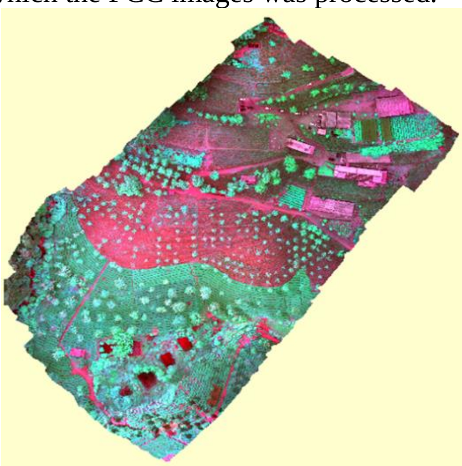


Fig. 12. False colour composite

4.4 Preparation and visualization of geo-spatial products – NDVI

NDVI is the ratio of difference in the Near-Infrared (NIR) and Red bands to the sum of the NIR and Red bands [10].

$$NDVI = \frac{NIR - red}{NIR + red}$$

where,
NIR – Near infra-red spectrum value
red – red spectrum value

Generally, the NDVI values above 0.7 indicates good vegetation, and values in the range of 0.03 to 0.2 shows barren land. In between these two values indicates lesser vegetation or grasses or bushes. In good vegetation areas the lighter colour difference indicates stressed and diseased plants.

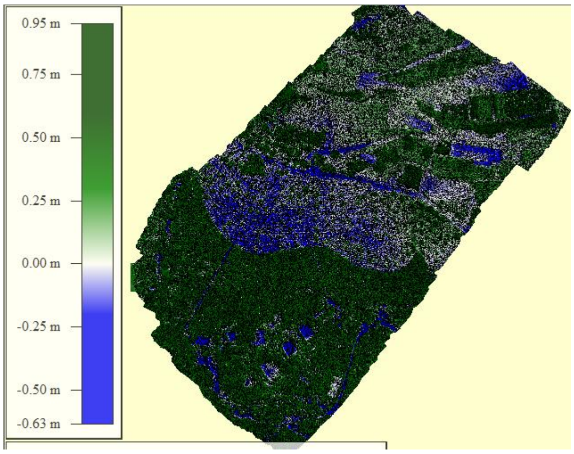


Fig. 13. NDVI Image in Global Mapper

Figure 13 shows the NDVI map in Global mapper output from the Agisoft Ortho mosaic output.

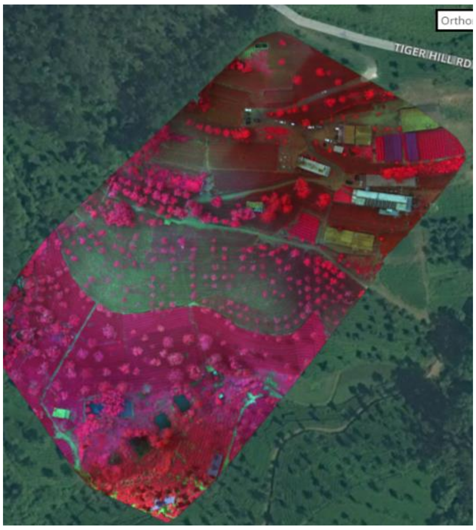


Fig. 14. Orthomosaic from Precision Mapper

The NDVI values lying between -1.0 and +1.0 is classified in to a number of categories shown below:

Table 3. Values of NDVI

NDVI Values	Corresponds to
Zero	No vegetation
-1	Deep water
-0.01 to 0.1	Barren areas of rock, sand, clouds and snow
0.1 to 0.2	Soil
0.2 to 0.3	Shrub and Grassland
0.3 to 0.8	Dense vegetation
Approach 1	Temperature and Tropical Rainforests

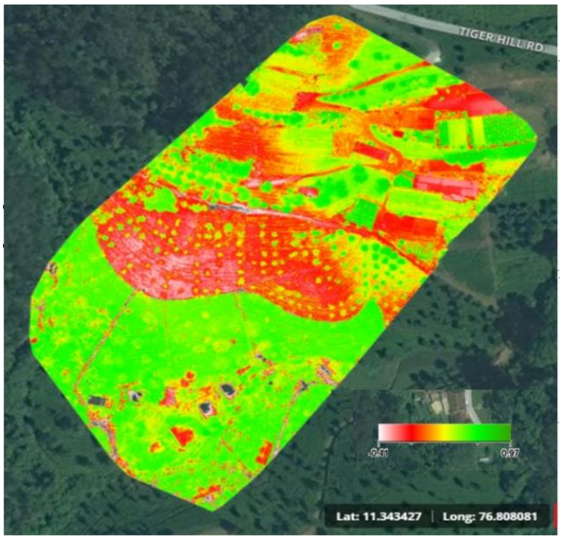


Fig. 15. NDVI from Precision Mapper

Fig. 16. NDVI in Pix4D Cloud

5 Conclusion

The precision mapper is a cloud-based software, which has the capability to automatically process the aerial data into 2D or 3D output. The algorithm available in the software facilitates the easy sharing of the output through other sources like mail. It can process a maximum of 5 spectral bands. The precision mapper software has various capabilities and can help in more than 15 different ways of analysis. The time consumption is comparatively lesser than the other two counterparts. Unlike Agisoft it doesn't require a separate software for NDVI calculations. The process is completely automatic and manual errors can be reduced. The comparison of results from three software are tabulated in Table 4.

6 Future work

The best software to process the NDVI analysis as a part of precision agriculture is carried out. Comparing the outputs of three software packages, Precision mapper suits best for the NDVI analysis. The further steps of the project utilize the NDVI analysis, find the location and geo tag the location. The geo tagged location will be given to the UAV for spraying optimal amount of fertilizers and pesticides. The future work of the projects is given below:

- Comparing the real-time work with software results and find the accuracy rate, such that it the technology can be improved for further accuracy.
- Extend the utilization of technology for various other plantation types to improve productivity and increase profit.
- Implement the other capabilities of UAS in precision agriculture such that a blend of agriculture and technology makes a new revolution in farming.

Table 4. Comparison of Software Results

	Agisoft	**Pix4d cloud**	**Precision Mapper**
Time	1 hr 15 min	Uploading Time: 20 min Processing Time: 2 hrs 15 min	Less than 2 hrs
Total image	695 out of 700	700 out of 700	700 out of 700
Quality	Medium	100%	
Rig name	Mica sense 5 band	Mica sense 5 band	Mica sense 5 band
Average GSD	6.55 cm	6.55 cm	6.55 cm
Area Covered	0.0609 Sq. km	0.0534 Sq.km	0.0513 Sq.km
Geo-tagged Image	Yes	Yes	Yes
DSM and Ortho-mosaic Resolution	6.59 cm/pixel	1 x GSD(6.55[cm/pixel])	6.82 cm/pixel
Index Calculator: Indices	No	NDVI	NDVI
Output from the Software	DEM and Ortho-mosaic	NDVI	FCC and NDVI
Report generated	Yes	Yes	No
Work flow	Manual	Automatic	Automatic
Analyse	2	1	More than 15

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