Applications of UAV Remote Sensing - Case examples of North Eastern Region

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ABSTRACT: Unmanned Aerial Vehicles (UAVs), popularly known as Drones, is an airborne system or an aircraft operated remotely by a human operator or autonomously by an on-board computer. UAV based Remote Sensing (UAV-RS) is the new addition to the North Eastern Space Applications Centre (NE-SAC) for large-scale mapping and real time assessment and monitoring activities of various applications.
NE-SAC has taken the initiative for design and assembling of UAVs for various applications. Different components of the UAV are selected based on the design parameters and assembled as per the requirements. A Hex Copter was designed and assembled at NE-SAC, which can carry maximum payload up to 2.5 Kg of different sensors such as thermal, multi-spectral, optical and hyper-spectral etc. Multiple UAVs have been procured with varying payload capabilities and supporting software tools for all State Remote Sensing Centres of North Eastern Region with the full financial support of North Eastern Council. NESAC is also venturing into fixed wing UAVs which will have higher flying time and thereby covering larger areas. The UAVs are added advantage of providing very high resolution imagery and the benefit of repeat coverage of any particular area, otherwise very difficult to obtain from satellites. The major advantage of UAVs is getting minute details, generation of seamless mosaics, DEMs with centimeter level accuracy, ortho photo and video coverage etc and useful for large number of applications
The NESAC has carried out large number application studies such as dam site analysis, rice crop infestation, landslides, urban studies, survey for butterfly park, cherry blossom mapping, flying of airport area and line of sight studies, multi-spectral studies of crops, mapping cultural events and its surveillance etc. The details of all the application studies carried out will be discussed as part of technical presentations.

1. INTRODUCTION

The development of low-cost unmanned air vehicles (UAVs) and light-weight sensors in the past decade has resulted in significant interest in their use for remote sensing applications (Hung et al., 2014).
The fundamental advantage of UAVs is that they are not burdened with the physiological limitations and economic expenses of human pilots (Everaerts J., 2008). UAVs are cheaper, smaller and lighter than manned aerial vehicles. UAV operations are far less expensive than any manned aircraft and far more environmentally friendly (generate less CO2 and noise). A typical UAV consists of an Unmanned Aircraft (UA), a Control System (CS), usually a Ground Control System (GCS) and a communications data link between the UA and the CS (Colomina and Molina, 2014) . Further, they can be operated frequently (weather permitting) at low altitudes, allowing the collection of data at high spatial and temporal resolutions.

There are wide range of applications, where use of UAVs has been found to be time and cost effective. These applications includes mapping and monitoring of crops, particularly precision agriculture farming, urban planning, disaster management etc. (Zhang et al., 2002, Grenzdörffer et al.,2008, Casbeer et al., 2006, Réstas, 2006, Martínez-de Dios, 2006). In case of Precision agriculture, UAVs have proven their importance in terms of field trials and research, determination of biomass, crop growth, crop damage assessment etc(Anen and Nebiker et al., 2008). UAV system was found to be effective in identifying the present vegetation and is possible to generate detailed map of vegetation assemblages at the species level (Arnold et al.,2013). The use of UAV in the application of urban planning is increasing as it provides high resolution imagery, Digital 3D models for a variety of applications such as urban planning, navigation, simulation, virtual reality, and entertainment. (Tokarczyk et al., 2015, Galarreta et al., 2015, Jenkins 2015). To achieve this capability on an operational basis requires an ability to put a suitable UAV with appropriate sensors in place above a disaster location and provide real-time, over-the-horizon data. (Martínez et al., 2006, Ollero et al 2006, Maza et al. 2011, Restas 2016 & 2006, NASA White Paper). Different sensors developed with optical, hyperspectral and thermal region of electromagnetic spectrum have brought out new possibilities of studying within field variations.

In hilly terrain such as in the north eastern region of India, there are challenges for remote sensing applications in terms of persistent cloud cover, undulating terrain, in accessibility and prone to most of the natural disasters. (Sahoo et al. 2005). In such situations UAVs have emerged as alternative and complementary solutions for remote sensing.
NESAC has taken the lead in use of UAVs for different applications in the region. [ACRS, disaster workshop reference].This paper presents the results and observations made from few case studies on crop discrimination and crop damage assessment, urban planning, identification of suitable sites for hydroelectical project and assessment of the embankment breach. The studies are expected to provide capability and reliability of selected UAVs for providing real time information in diverse applications.

2. METHODOLOGY

2.1 Design and development of Hexacopter:

A Hexacopter/multirotor has been developed at NESAC which has seven main sections, the frame, the propulsion, the power, the radio control, the flight control system, the ground station and on-screen display unit and an additional section which is not required for flight, but for a mission in general, the payload. Each of these sections is dependent on one another to achieve a fully functional and efficient multirotor system. The frame of the multirotor system provides a platform to place the components of the multirotor and also protects them from FOD (Foreign Object Debris). The propulsion system is what lifts the multirotor system off the ground. The propulsion system consists of the propellers, the motors and the necessary driving electronics. The flight control system is the nub of the moderator and it controls the multirotor making it fly accurately and in a stable manner. The flight controller consists of a microcontroller, sensors and a receiver to gather data from the ground station. Finally, the payload drives a multirotor system based around the payload. Based on the above studies and design the Hexacopter has been assembled as shown in Figure 1. After assembling the systems test flights were conducted.

Figure 1: Assembled Hexcopter

2.2 Use of UAV for various applications:

We have used an two UAVs manufactured by DJI i.e. Inspire 1(Figure 2) and Matrix-600 (Figure 3). Two sensors, one optical camera, X3 FC350 and other Parrot Sequoia multispectral sensor were employed onboard the UAVs for the selected studies. Salient technical specifications of UAVs and optical sensor are given in Table.1

Figure 2. DJI Inspire 1 UAV

Table 1. Technical specification of aircraft and the camera of the UAV

Aircraft			**Camera**	
Model	DJI Inspire 1 (T600)	DJI Matrice 600	Name	X3
Weight (Battery Included)	2935 g	9.1 kg	Model	FC350
Dimensions	438x451x301 mm	640 mm x 582 mm x 623 mm (Frame arms and GPS mount folded)	Effective Pixels	12.4M
Hovering Accuracy (GPS mode)	Vertical: 0.5 m Horizontal: 2.5 m	Vertical: 0.5 m Horizontal: 2.5 m	FOV (Field of View)	94°
Max Speed	22 m/s (ATTI mode, no wind)	Approximately 45 minutes	Photo/Video format	JPEG, DNG/MP4 MOV
Max range	2000 m radius (with line of sight)	5000 m radius (with line of sight)	Lens	20mm Anti-distortion
Max Height	2500 m		Still Photography Modes	Single shoot Burst shooting: 3/5/7 frames Time-lapse
Max Wind Speed Resistance	10 m/s		Video Recording Modes	UHD (4K), FHD, HD
Max Flight Time	Approximately 18 minutes (per battery)		Supported SD Card Types	Micro SD Max capacity: 64 GB. Class 10 or UHS-1 rating required.

Figure 3. DJI Matrix 600

2.3 Parrot Sequoia sensor

For agricultural applications multispectral Parrot Sequoia sensor having four bands Green, Red, Red edge and NIR is used. The Sequoia sensor comprised of two sensors i) the multispectral sensor and ii) the sunshine sensor. (Figure 3) The multispectral sensor containing five bands i.e. Green, Red, Red Edge, Near Infrared (NIR) and one RGB Sensor mounted underneath the drone facing towards the Nadir. The sensor has length of 59 mm, width of 41 mm and height of 28 mm (Table 3).

The Parrot Sequoia sensor has a built-in GPS module. While the GPS modules integrated into UAV made it possible to keep an eye on their position during a flight, the Sequoia GPS module allowed the position of each captured image to be identified. The GPS module made it possible to significantly increase the precision of the data collected by the sensor without using data collected by the transport platform: plane, drone, tractor, etc. The integration of a GPS module into the sensor fulfilled the objective of rendering Sequoia fully autonomous, thus dispensing with image monitoring by the autopilot of the drone. As a result, it could be used in any drone.

Table 3: Details of bands in the multi-spectral sensor (Source : www.parrot.com)

Band Name	**Central Wavelength (in nm)**	**Band width (in nm)**
Green	550	40
Red	690	40
Red edge	735	10
NIR	790	40

Figure 4:Parrot Sequoia Multispectral sensor and Sunshine Sensor

The sunshine sensor was mounted above the drone facing towards the zenith or the sky. The sunshine sensor assisted in adjusting the light variability, which occurred during the same acquisition or two different acquisitions taken at two different times of the day of the earth features. This sunshine sensor was very important in the clear as well as overcast conditions of north east India thus improving the results. The sunshine sensor has length of 47 mm, width of 39.6 mm and height of 18.5 mm.

2.4 Data collection and analysis

The survey was conducted at various locations in Meghalaya and Assam. Necessary permissions were obtained from the concerned authorities for the UAV survey. For agriculture crop study the time period was chosen such that there was maximum difference in terms of vegetation growth, one during pre monsoon and another during peak monsoon period. The time of the day for data acquisition for agriculture study was taken such that sun was vertical above with maximum illumination. To avoid image distortion and shadow effects, the camera was tilted 90^0 vertical down at all study areas. The height of the UAV was maintained at 120 m. At this height ground resolution obtained was approximately 5cm. Multiple images were obtained at the speed of one image per 5 seconds. The images and the videos were transferred to the computer and processed. Orthomosaic and Digital Elevation Model(DEM) is generated according to the requirement.

3. CASE STUDIE USING UAVS

3.1 Case study 1: Crop discriminations and damage assessment using UAV

The exercise was carried out in selected sites in West Jaintia Hills district of Meghalaya state in north east India for discrimination of different crops. Parraot Sequoia sensor having four bands with Green (550 nm), Red (690 nm), Red edge (735 nm) and NIR (790 nm) has been found to be effective in crop discrimination based on variation in spectral response of different crops. Multispectral temporal data was processed and the four bands(Green, Red, Red edge and NIR) were stacked together and vegetation indices (NDVI, NDRE, GNDVI) were generated (Ustuner et al). Discrimination of four horticultural crops viz. banana, orange, and plum and the neighbouring bamboo grooves were evaluated using the three commonly used indices viz., Normalized Difference Vegetation Index (NDVI), Normalized Difference Red Edge Index (NDRE) and Green Normalized Difference Vegetation Index (GNDVI). NDVI and GNDVI showed nearly similar spectral response, where bamboo areas were having adjacent values with orange and banana. Separability among the crops marginally improved with the use of NDRE. The percent variations of orange to bamboo were 14 and 19 for NDVI and GNDI against 49 in case of NDRE.   Similarly, percent variations of banana to bamboo were 7 and 15 for NDVI and GNDI against 27 in case of NDRE.(Figure 5)

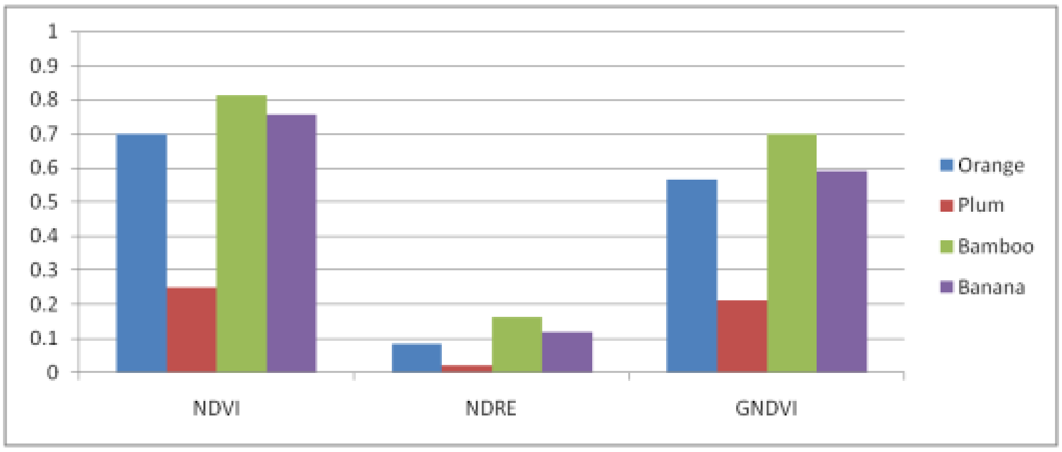

Figure 5: Response to the vegetation indices for selected crops

Another exercise was carried out in Morigaon district of Assam to assess the pest infestation in *Boro* paddy (summer paddy) infested by Brown Plant Hopper (BPH) *Nilaparvata lugens* (Stal). The survey was conducted in four locations reporting severe infestation by plant brown hopper in the district of Morigan viz., Naramari, Mikirbheta, Bhurbandha and Jaluguti. Necessary permissions were obtained from the local administration for the UAV survey. The first UAV flight was conducted in Naramari village under Mayong development block reporting severe infestation of BPH. A total area of 54.94 ha was covered with flying time of 15 minutes. The height of the UAV was maintained at 240m. At this height ground resolution obtained was about 50cm and the infested areas could clearly be identified. Multiple images were obtained at the speed of one image per 5 seconds. The second flight was undertaken in Mikirbheta village under Mikirbheta block covering an area of 24 Ha.. As the infestations were more sporadic with smaller in size, the lower flying height could give better discrimination of infested fields.
The survey in the third location in Bhurbandha under Morigaon block was conducted for both image and video recording. In the fourth site in Jaluguti an area of 32 ha was covered and varying size of infested areas was observed in this site.

The images were transferred to the computer and processed with Pix4D software. Mosacing of the images done to have seamless boundaries of the scenes. Digitization of the rice fields were done along the field boundaries. Based on the severity of infestation, fields were categorized as completely affected, partially affected and other fields. The infestation which occurs as a result of feeding by both nymphs and adults of the insect at the base of the tillers, plants turn yellow and dry up rapidly. It was observed that at early infestation, round, yellow patches appear, which eventually turn brownish due to the drying up of the plants. The infested fields could clearly be identified in the images based on the tonal variations with the healthy rice fields . Rice plots having more than 50% infestation, categorized as completely affected, less than 50% is categorized as partially affected. It has been observed that there will be hardly any yield from the plots categorized as completely affected; whereas with immediate intervention measures, part of the crop areas could be saved.

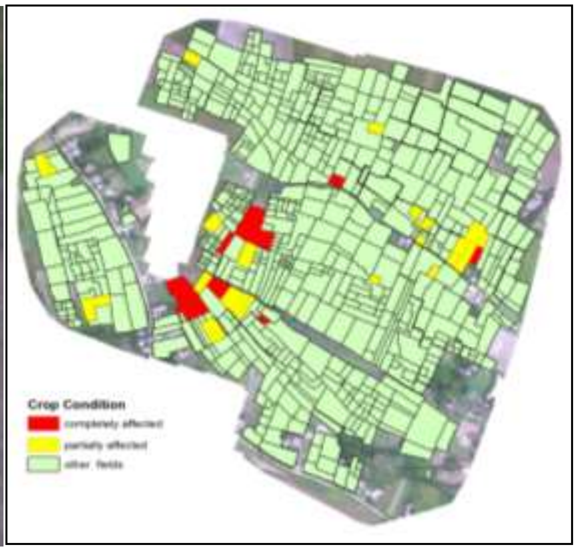

Figure 6: Infested fields in Naramari

Figure 7: Categorization of BPH infested rice fields

3.2 Case Study 2. Urban planning using UAV data

Urban planning is concerned with the development and use of land, protection and use of the environment, public welfare and the design of the urban environment (air, water, and the infrastructure- transportation, communications, and distribution networks).

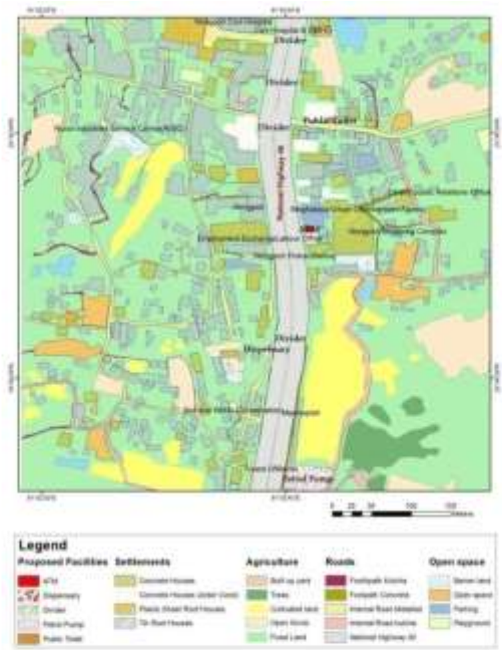

Figure 8: UAV Image of Nongpoh Town

Figure 9:Proposed location of amenities in Nongpoh

It was taken up to identify the existing urban land use/ land cover areas and to its suitability analysis for location of amenities in part of Nongpoh Town the district headquarter of Ri Bhoi district in Meghalaya state (Figure 8). The study area extends from 25˚54 ′15 ″N - 25˚ 54′ 35″ N and 91˚ 52′ 29″E - 91˚ 52′ 48″ E and covers an area of 0.33 Sq.km. Detailed existing urban features was prepared and also suggested the proposed amenity locations in the town.(Figure 9)

3.3 Case study 3: Identification of suitable site for hydro-power project

North Eastern Electric Power Corporation Ltd. (NEEPCO) is working on a project of constructing a hydropower dam on Umiew river near Mawphu village in East Khasi hills district of Meghalaya. For initiating infrastructure and connectivity to the dam site and large scale mapping of dam and surrounding areas were planned with UAV based survey. A high-resolution photography and videography was done for the dam and powerhouse area including the roads nearby from a height of 120 m and the seamless mosaic (Fig 1) with 5 cm resolution along with the full HD video was given to the NEEPCO authority.

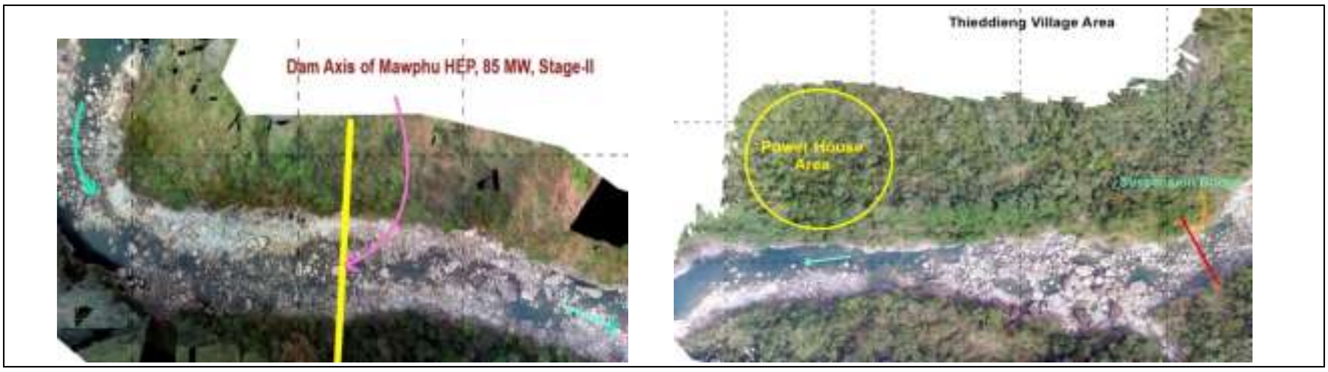

Figure 10: Mosaic of Dam and power house locations of Mawphu stage II project

3.4 Mapping of embankment breach location in Majuli Island

Majuli island located in Assam is the largest river island in the world. The island is frequently suffered from flood due to embankment breaches. UAV survey was carried out for mapping the embankment breach location and the surrounding affected areas. The image was acquired with a ground pixel resolution of 5 cms taken from a embankment breach(Figure 11). The extent of damage of the embankment and the affected areas was mapped and provided the information to the water resource department of Assam for taking necessary intervention measures(Figure 12).

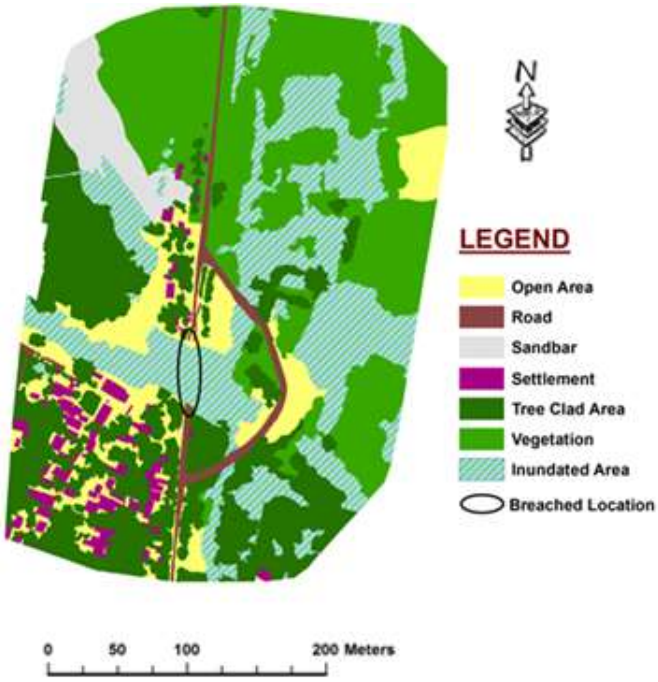

Figure 11. UAV image of the embankment   Figure 12. Classified map showing breaching location

4. CONCLUSION

A low-cost aerial sensing system can benefit users to accomplish various critical applications. High resolution UAV imaging can provide opportunity to explore new applications that are not available today with current aerial imaging systems. Ease of operation and ability to obtain very high resolution aerial images may be an attractive tool for precision agriculture in north eastern region of the country. In this work, we present few potential applications of a reliable, robust multi-rotor remote sensing system that is capable of acquiring high resolution aerial images (1 inch or better). Results from our preliminary work indicate that such remote sensing technology can aid in improving the management efficiency. The result from survey of pest infected crop fields shows the effectiveness of using UAV in damage assessment and suggests that it will open up new dimension in providing critical inputs for various crop insurance schemes in the country. Similarly, it will open up new areas of applications in the area of urban planning and disaster management in NE region of the country.

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