Low Altitude Remote Sensing and its Application in Precision Agriculture: A Case of Nzathu Farm in Traditional Authority Somba in Blantyre District, Malawi

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Introduction

- Modern agriculture has seen a growing need by progressive farmers to have timely information about crop and soil conditions for farm management purposes.
- Hence the use of PA technologies is a major direction.
- PA aims at defining a decision support system for whole farm management so as to optimize returns on inputs while preserving resources.
- Variable Rate Technologies (VRT) and GPS are therefore used to achieve this aim.

- However, the challenge now is obtaining up-to-date data for crop and soil conditions for VRT.
- Historically, zonal maps have been created by applying yield maps from yield monitors. However, these maps too are unreliable and limited because:

a) They are generally acquired once a year.

b) They display a huge variation when observed.

c) Are only available after the season, when many harvesters are still not equipped with yield monitors.

- The alternative is to utilize remotely sensed imagery acquired during the growing season.
- Information about soil and crop condition can be obtained from high spatial resolution satellite imagery for crop yield predictions.
- However, weather conditions and satellites' poor spatial and temporal resolution restrict the image availability for these sensors.

Further alternative is the utilization of airborne multispectral and hyperspectral sensors.

WHY???

These sensors have

- a finer spatial resolution
- real-time monitoring capability, and
- The development of Low Altitude Remote Sensing Systems (LARS) makes its application for PA possible.

Through assessing the spectral information together with ground collected biophysical data, monitoring within-field crop variation can be feasible using LARS.

- This presentation illustrates the utilization of self-build unmanned aerial vehicle (UAV) in monitoring crop and soil conditions on Nzathu Farm.
- It demonstrates that both optical and near-infrared imageries obtained from LARS can be used to monitor fertilizer trials, conduct crop investigation and mapping of field surface drainage.

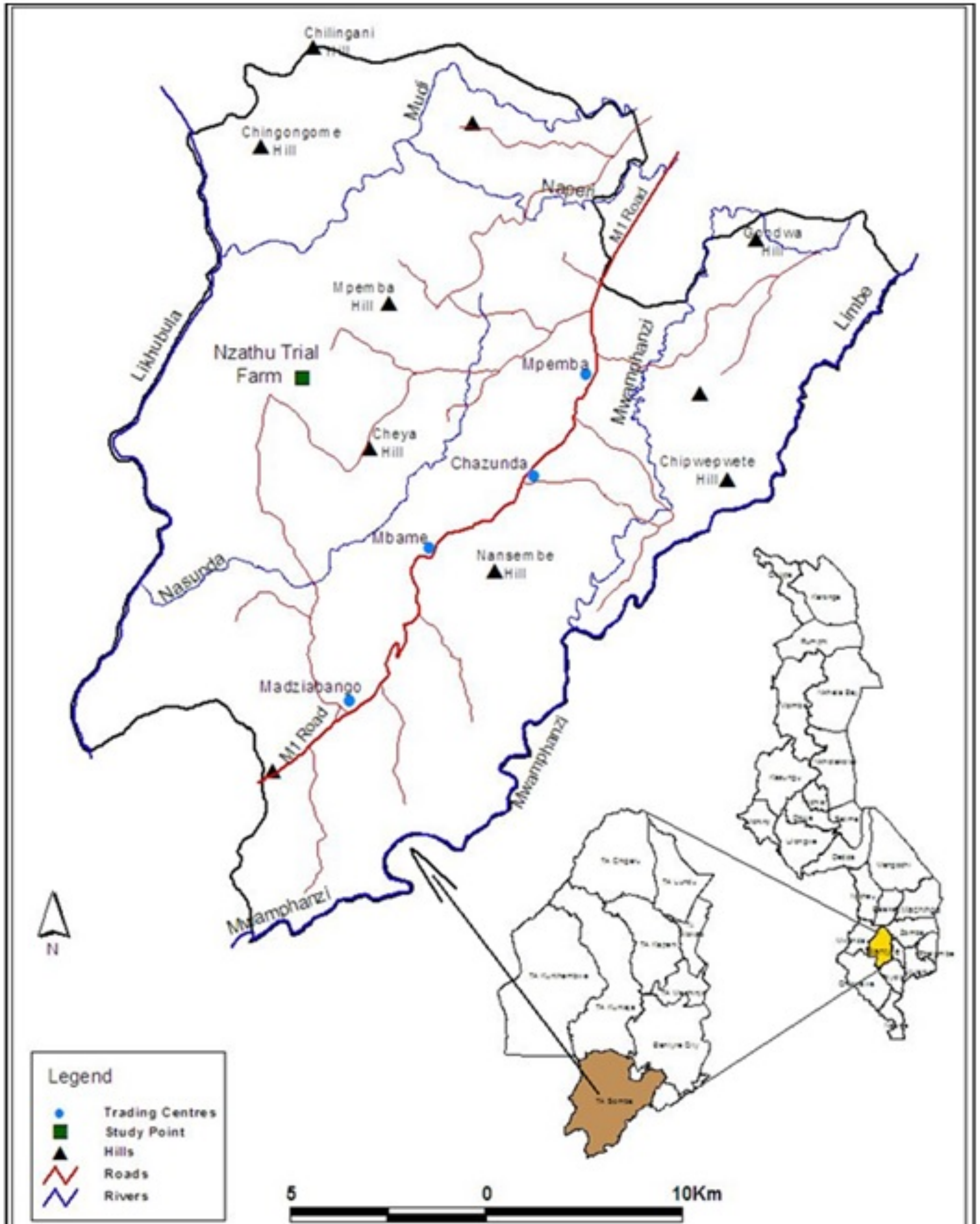

Fig. 1. Map of TA Somba showing study point

Equipment and Methods employed

- The UAV used was developed by Manuel Kiewisch, a UAV technologist and research scientist of University of Technology, Germany.
- It weighed 3.4 kg.

	Hexacopter Technical Overview	
Component (brand name)	**Function**	**Specifications**
Motors (AC 2836-358)	To provide lift and steering	Max. 880Kv (Rounds per minute per Volt)
Telemetry (Xbee Pro S1)	To enable wireless communication with PC	900 Mhz module, ca. 800m range
Frame (n.v.)	For stability and functional setup for the parts (anchorage)	Aluminium/glass fiber frame, ca. 50cm in diameter
Batteries (Turningy)	To provide power source for all energy consuming components	3S3P3 cells in series (3 cells in parallel), 3000 mAh (milli Ampere), 11.6 Volt
Chipset (Ardupilot Mega 2.0)	To enable communication between parts, steering, autopilot, and sensoric	Magentometer (stabilization in air), GPS (localization), Sonar (altitude measurement)
Remote Control (Spectrum DX7)	To enable manual control of the UAV	900 Mhz module, range ca. 800m, 7 channel setup
Camera (Canon PowerShot S95)	To record aerial optical ground information for remote mapping, study processes	10 Mega Pixels resolution, compact digital camera, ca. 260gr

Fig. 2. Self-made UAV and its control deck

- The capture images (in near infrared, red and green bands) were stored directly on a flash card located in the camera.
- The flight altitude was set at 60 meters. Hence the camera had a spatial resolution of 5cm.
- Since the field had one crop only, the front overlap and side lap were 85% and 65% respectively.
- 6 GCPs (Trimble GeoXH GPS) were set up throughout the field for orthorectification and georeferencing of the final mosaic images.
- 3 people were required for each flight mission.
- Each raw image was converted into a jpeg file and calibrated using *Pixelwrench2* software.
- Pix4d Mapper (*Pix4D, Switzerland*) software was used to orthorectify and mosaic the imagery and to generate NDVI images.
- A stratified random sample was used to statistically examine the differences in NDVI among the three fertilizer treatments.

Study Results and Discussion

Assessing fertilizer treatments using UAV imagery

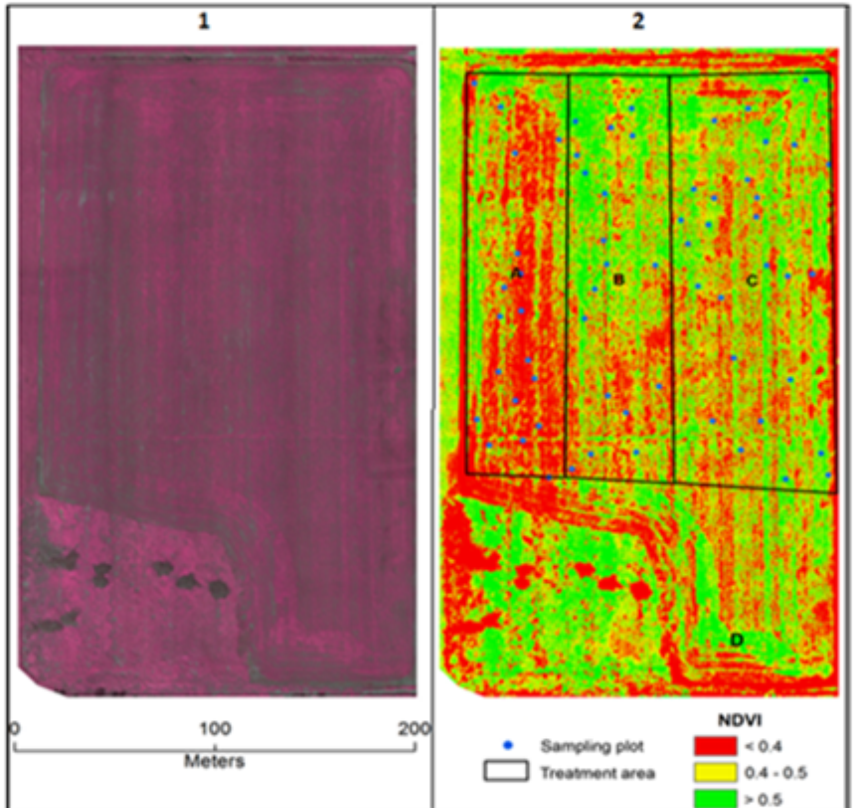

Fig. 3. Mosaicked image of maize as captured by the UAV (8 December 2015)

Image 1: mosaicked infrared color composite image (NIR, red, green - no enhancement applied.

Image 2: mosaicked NDVI image.

Area A: is treated with organic fertilizer.
Area B: is treated with both organic and chemical fertilizer.
Area C: is treated with chemical fertilizer only
Area D: shows an error in fertilizer application.

Calculated final yields for areas A, B & C were at 1.23, 1.77 & 2.47 tons/ha respectively.

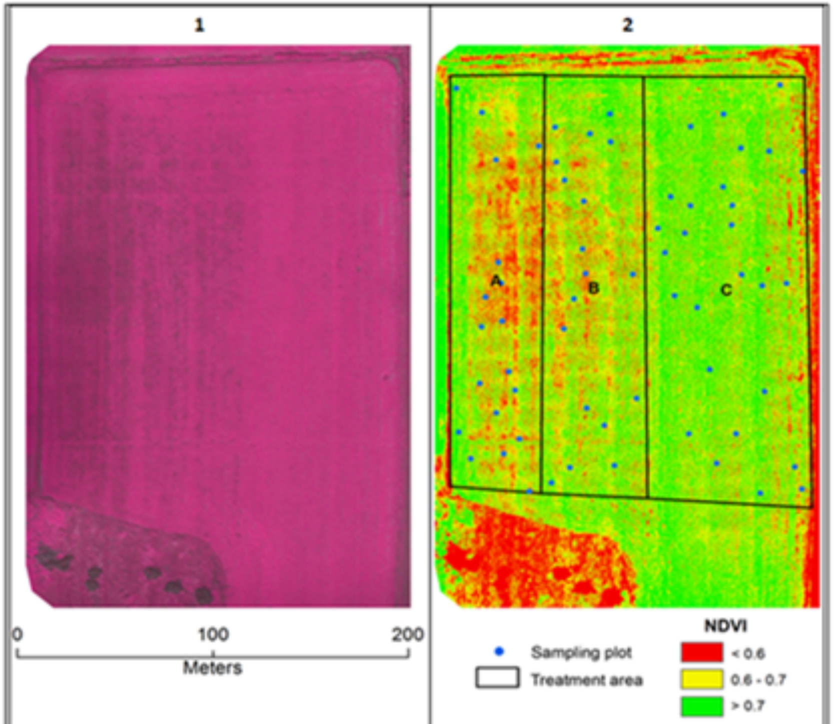

Fig. 4. Mosaicked image of maize field as captured by the UAV (20 January 2016)

Image 1: mosaicked infrared color composite image (NIR, red, green - no enhancement applied.

Image 2: mosaicked NDVI image.

Area A: is treated with organic fertilizer.
Area B: is treated with both organic and chemical fertilizer.
Area C: is treated with chemical fertilizer only
Area D: shows an error in fertilizer application.

Calculated final yields for areas A, B & C were at 1.23, 1.77 & 2.47 tons/ha respectively.

- First flight was on 8th December 2015. Maize crop was about 35cm high (Figure 3). Second flight was on 20th January 2016.
- The area treated with organic fertilizer had the weakest vegetation vigor hence appears much darker in the infrared image.
- Its NDVI values are considerably lower than those of the chemical fertilizer treatment (i.e. $P<0.001$).
- No much difference between areas **B** and **C** ($P = 0.59$).
- The NDVI difference between areas **B** and **C** is much apparent in images taken on 20th January 2016 (Figure 4) when the crop was at a later growth stage.
- Major differences (i.e. $P<0.001$) were observed between treatments **A** and **C**, and **B** and **C**. While the differences between treatment areas **A** and **B** were not statistically significant ($P = 0.07$), the P values is really close to the critical value of 0.05. Therefore, a flight taken between these two dates would have provided better discrimination of the treatment areas.

Identifying area of lodging and insect infestation using UAV imagery

- One typical pest that attacks maize in Malawi armyworm.
- It is estimated that, on average, one caterpillar needs 140 cm^2 of leaf area to develop through 6 instars. However, the 6^{th} instar itself requires 77.2% of that leaf area (Zhang et al 2012).
- Farmers therefore may ably recognize and report the armyworm infestation at this stage of growth.
- Loss of flag leaves and increased exposure of the soil surface and shadows, increases reflectance in the NIR band and reduces that of the red band.
- Armyworm infestation and stormy weather conditions rendered the maize crop more susceptible to lodging.
- Therefore, lodged areas appear as a bright red tone in the infrared image. Since the lodged maize crop covers the bare soil, stronger reflectance is observed from the leaves and stalks in the IR band giving a large contrast between the lodged and non-lodged areas.

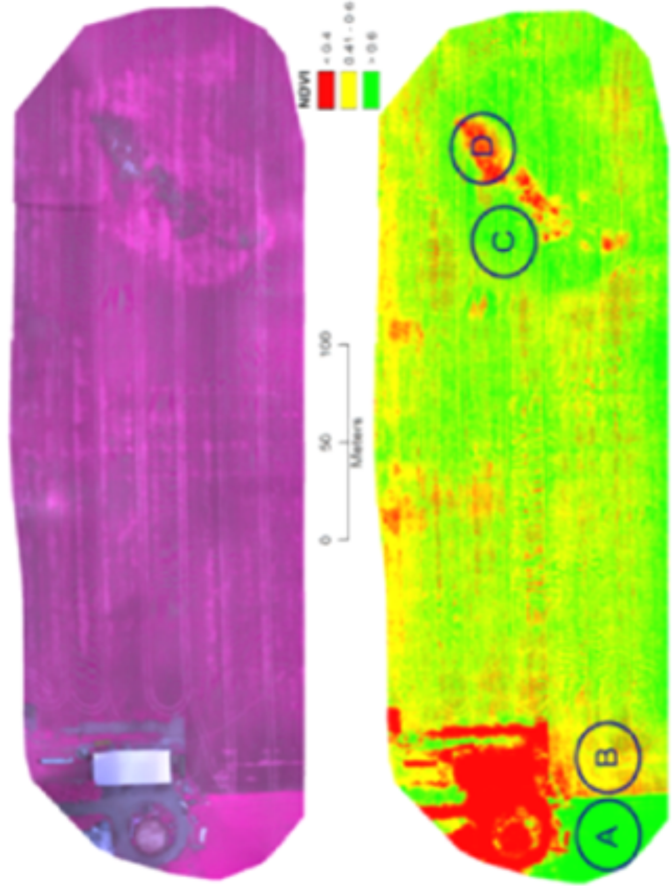

Fig.7. Mosaicked infrared color composite image (No enhancement) **NDVI derived image**

Left Image: a mosaicked infrared color composite non-enhanced image (NIR, red, green) whose plants are infested with both armyworm and lodging.

Right Image: corresponding NDVI derived image.
Area A: a healthy non-infested maize field
Area B: a section of the maize crop attacked by armyworm whereas
Areas C & D: sections of lodging and rock outcrop, respectively.

- Stressed areas (crop on shallow soils) were also identified.
- In the NIR, stressed crops are shown in a dark tone.

Such information may be used to determine

- ❖whether a farmer should invest in equipment to lift the lodged heads during harvesting.
- ❖the mechanism to be put in place to improve the fertility of the shallow soils.

Identifying field tile network using UAV imageries

- To reduce risk of crop failure due to excess water and maintain uniform crop production amidst climate variability the use of field tile drainage system were adopted.
- Good drainage reduces the frequency of pests and disease outbreak while ensuring that a farmer gets a modest return.
- Once installed these drainage systems need to be monitored and maintained hence it is necessary for the farmer to know the exact location of the tiles.

- The images for this task were collected on 17th March 2016, immediately after harvest.
- Linear enhancement was applied, and were mosaicked.
- Upon analysis, locations of some of the tiles in the image were identified.
- A brighter tone with a linear-like feature represented the locations of the tiles.
- Well drained areas were drier hence looked brighter.
- Areas of excessive wetness were darker.

NOTE:

- Interpretation was possible where the soil was bare as opposed to where remains of maize stalks were present.

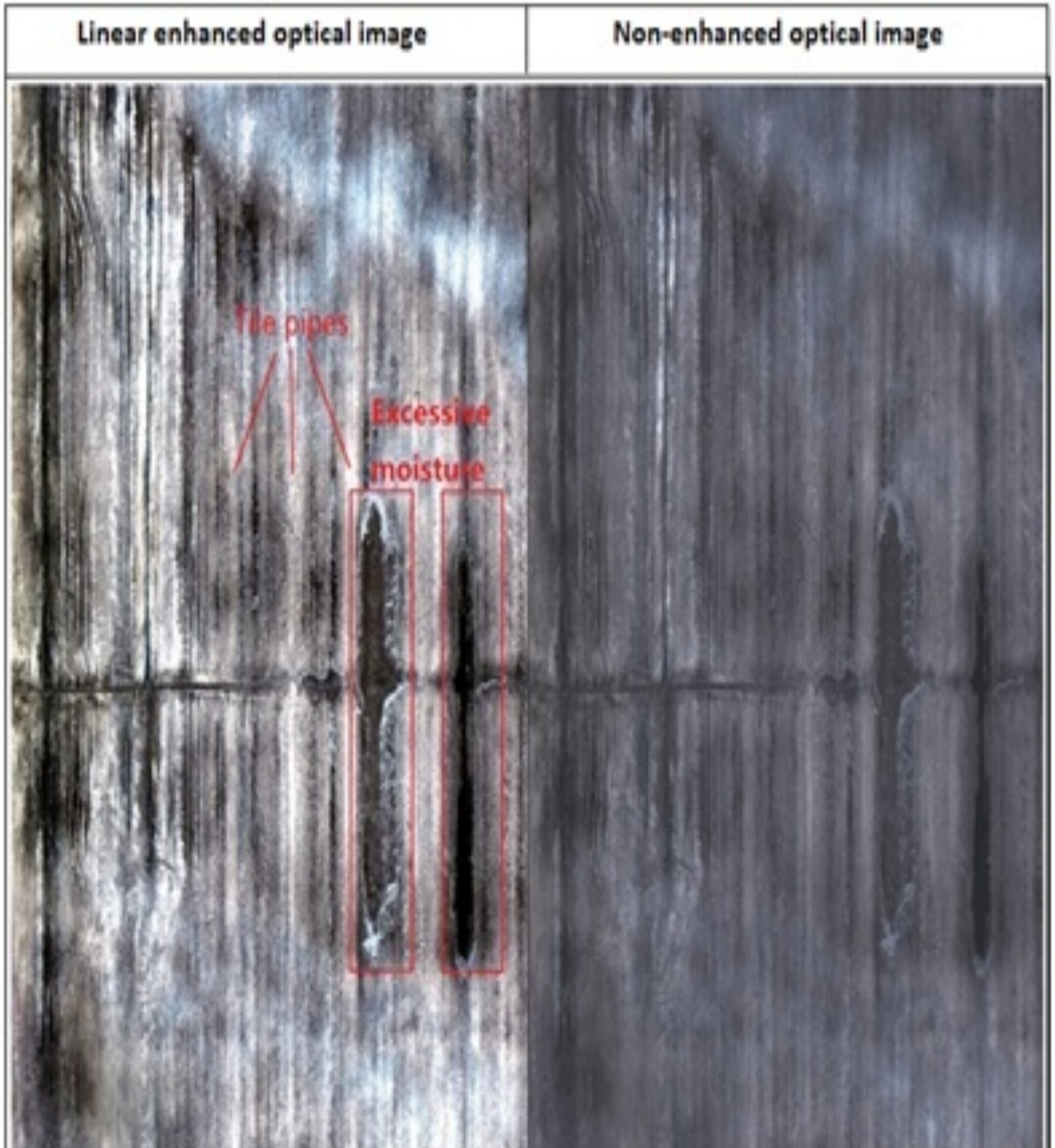

Fig. 8. Mosaicked image map for tile drainage pipes as captured by UAV

Conclusion

- UAV acquired images, both in optical and near-infrared, can be used for monitoring crop conditions in precision agriculture.
- Images can be acquired and processed in a timely fashion for PA applications.
- However, high current costs and operational logistics have compromised the assimilation of its application.
- Nevertheless, it is anticipated that as the costs of LARS decrease and more experienced personnel available to acquire and process the data, the adoption of UAV systems will skyrocket.