PRECISION AGRICULTURE: UAV-BASED SOIL MAPPING AND REMOTE SENSING APPLICATIONS

ABSTRACT:-

Using Unmanned Aerial Vehicle (UAV)equipped with remote sensing cameras that measure the electromagnetic spectrum of light reflected back from the ground below, this technology does soil mapping and field analysis. The way that different elements reflect different light wavelengths can be used to identify them. Reams of data on those wavelengths are gathered by multispectral image sensors, which power sophisticated AI software that can identify even the smallest variations in the elemental composition of soil. There are numerous positives to soil mapping, including helping farmers choose the best crops, applying the right fertilizers, and scheduling irrigation. Soil mapping also makes it easier to create plans for soil conservation and restoration that work. UAVs facilitate rapid deployment, enabling data collection near end-users, while delivering a more comprehensive and precise dataset compared to traditional camera-based methods. This study will provide effective technical support and decision-making assistance for future agricultural land planning.

KEYWORDS:- Unmanned Aerial Vehicle (UAV), Soil Mapping, Spectral Imaging, Image processing, Soil.

INTRODUCTION:-

Throughout the history, agriculture is one of humankind's oldest industries and has continuously embraced technical innovations to increase output. But the growing world population also brings new difficulties, such as the urgent need to ensure enough food for everyone. Traditional tillage methods and technology are ineffective in meeting these modern needs. As a result, superior data-driven precision agriculture has become an essential component of contemporary farming methods.

Healthy soil is an essential component of agriculture and the base of the food chain. Nutrient-rich soil is essential for the growth of all food-producing plants, and it has a direct effect on the number and quality of crops that support human and animal populations. A stable base for food-producing plants to grow and thrive is provided by healthy soils, which are rich in vital nutrients, water, and oxygen. Additionally, soil serves as a buffer, preventing abrupt temperature changes from damaging sensitive plant roots and guaranteeing ongoing productivity. Because different crops do better in different types of soil, farmers must make informed decisions regarding crop selection based on their awareness of the properties and composition of their soil. Soil mapping plays a pivotal role in providing crucial insights into soil composition for farmers. This process involves systematically observing and documenting the various types of soil and their distribution within a given region.

Using advanced geographic information system (GIS) mapping techniques and photogrammetry for landform identification, a detailed understanding of on-the-ground conditions can be produced for large amounts of land in just a short amount of time.Modern agricultural operations depend on the monitoring of soil conditions and composition; as with most things, the more precise the data, the better; multispectral soil quality maps let farmers decide when and where to make adjustments in relation to crop planting (Koomans Ronald *et al.,* 2022).UAV i.e. drones have the potential to significantly enhance agricultural productivity by providing invaluable information and insights beyond farmers' traditional reach. Also, drones streamline labour intensive activities such as scouting for pests, applying fertilizers, pesticides, and harvesting, thereby enabling farmers to allocate their efforts toward marketing and refining land management practices (McCarthy *et al.*, 2023).

MAPPING OF SOIL TEXTURE USING UAV BASED HYPER-SPECTRAL IMAGING:-

One of the most significant physical and inherent characteristics of soil is its texture. Traditional soil texture measurement methods rely on field soil sampling and laboratory chemical analysis, which are time-consuming, laborious, and costly, making it difficult to conduct large scale and multi-frequency soil texture content monitoring (Pu*et al.,* 2020, Lagacherie*et al.*, 2008). The monitoring of soil texture with non-imaging geophysical spectrometers is a major area of current research. Less research, nevertheless, has used hyperspectral data from unmanned aerial vehicles (UAVs) to track soil texture. High-resolution spatial information about soil texture can be promptly and precisely obtained using hyperspectral sensors placed on unmanned aerial vehicles (UAVs). The groundwork has been completed for the use of unmanned aerial hyperspectral data collection in lieu of field sampling to enable quick soil texture studies.

In recent years, rapidly developing vision-near-infrared hyperspectral technology has been widely used in soil texture content estimation to address the contradiction between the demand for big data of soil texture and high cost (Stenberg B, et al., 2017). Depending on the spectral response relationship between soil spectral reflectance and soil texture, many researchers have used ground object spectrometry to develop soil hyperspectral technology as a conventional means of quantifying soil texture(Azizi *et al.*, 2023, Kaya *et al.*, 2022, Omondiagbe *et al.*, 2023). However, soil texture inversion based on a ground-object spectrometer usually obtains spotlike data with low density. This makes it difficult to meet the requirements of rapid visualization of spatial distribution in the context of precision agriculture (Shu *et al.*, 2022). UAV platforms have the advantages of mobility and flexibility and have been widely used in land resource space surveys in recent years(Gu *et al.*, 2019).

As emerging tools, UAV have the advantages of portability, high spatial resolution, high flexibility, independent selection of flight time, and the ability to carry a variety of spectral cameras (Ma *et al.*, 2023). This can quickly and efficiently achieve remote sensing image (Figure:1) acquisition in a specified area (Ge *et al.*, 2019).A UAV hyperspectral system is an effective tool for monitoring and mappingthe spatial distribution of soil textures. F

Fig. 1: The flight paths: RGB (above), NIR-RG (below).

The hyperspectral camera carried by UAV can not only obtain ultra-high spatial resolution images, but also centimeter-level remote sensing images of farmland rapidly and inreal time (Chen *et al*., 2021).This means that they can be used to effectively assist agricultural operators in operation management and regulation (Hu *et al*., 2019).

CHARACTERISTICS OF UAV AND IMAGE PROCESSING:-

Aerial images were obtained using an unmanned aerial vehicle (UAV) carrier platform. The fight planning with the ground control unit was prepared using "Missionplanner". The carrier, namely the Multispectral Camera (Tetracam ADC Snap) mounted on the UAV, was used as the sensor. The camera, mounted on the UAV, had 3 flters to constrain the refection ranges and allow to acquire the green, red and near infrared wavelengths, equivalent to the Landsat Thematic Mapper bands of TM2, TM3 and TM4. The TM2, 3 and 4 bands are the basis for standard-false color composite images associated with multi-spectral images, which are used to monitor the changes occur due to plant stress and to evaluate the growing environment under special plant and soil conditions. A 5×5 median flter was used to the cropped images to reduce dust, spores and water that decrease the quality of images obtained from natural environments (Soviany, 2003; Tetracam, 2019).

The height for aerial images was approximately 50 m determined depending on the current conditions of the land, fight safety and the sensor used. The forward and side overlap ratios of the images were 80 and 60%. The fight was carried out with an estimated resolution of 3.99 cm and a total of 122 aerial images were taken for the study. Pixelwrench (Tetracam, 2016), Photoscan (Agisoft and St Petersburg 2016) and ArcGIS software were used in the processing, evaluation and visualization of images (ESRI, 2010). The planned fight time in a light windy and cloudless weather was approximately 5.31 minutes. Unprocessed/raw multispectral images obtained with Tetracam were processed using Pixelwrench 2 software. The Pixelwrench2 performs image processing and editing and capable of extracting various vegetation indices such as NDVI from images. The raw data was first colored and converted to TIFF format for photogrammetric processing (Heinold, 2007; Tetracam, 2016).Orthophotos were obtained from aerial images produced in NIR/R/G bands using Photoscan software (Fig. 2, Šedina *etal*., 2018). The images were placed on the fight line according to the structure from motion (SfM) principle and a dense point cloud was obtained (Agisoft and St Petersburg 2016). The root-mean-square error (RMSE) that occurred at the end of this process was 0.392 pixels. Total RMSE in the geographic coordinate obtained for the image processing was 0.09 mother orthophoto resolution obtained using the UAV images was 3.21 cm/pixel (Dindaroğlu *et al.*, 2017).

Fig. 2: NIR orthophoto from top and bottom.

Pre-processing of UAV images:-

The UAV's flight route was examined in Sbgcenter software for pre-processing, and the flight path data was exported. The exported flight path data was then segmented and erroneous routes were eliminated using Omap software. A complete hyperspectral image was obtained by pre-cutting the hyperspectral image using software from Airline Division in accordance with airline conditions. Using MegaCube software, radiometric calibration and atmospheric correction were applied to the cropped image. After that, the updated picture was loaded into ArcGIS for geographic registration. The reference data were the remote procedure call file delivered by the UAV and the orthographic base map taken. After registration, the images sliced using *ENVI* software. *MegaCube* software was used to create an image hypercube, which was then converted into a hyperspectral image. Therefore, pre-processed vis-Near and NIR images were obtained. The coordinates of the actual sampling points were imported into the hyperspectral image to obtain the UAV spectral reflectance data of all sample points, and noisy bands were removed (Qi Song *et al.*, 2023).

Measurements from the survey:-

Since it was challenging to calculate the distances to the sample regions using the mark sizes, navigation depended on the distance readings; thus, a better scaling of the virtual objects' sizes is required. In addition to scaling virtual items according to the user's distance from them, Wikitude also allows users to scale things to change how big they appear to be in their field of vision. This test indicates that further testing with this value is required.

Since the items seemed closer to the user than the distance numbers suggested, they ought to be resized to appear smaller. The radar's size is another scaling issue that has to be improved because the objects were difficult to identify. The radar's dimensions need to have been adjusted to correspond with the field's greater size, as previous testing used a somewhat smaller test field.

Conclusion:-

The findings demonstrate that a set of optimal processing techniques can be obtained by combining machine learning with hyperspectral data from UAVs. By pre-processing the spectral data, it is possible to estimate soil texture with high accuracy and achieve good mapping result. This soil mapping and sensing technique will be well utilized in future and will have great demand. It not only relies on UAV, but also includes various aspects of precision agriculture. Soil Organic Matter can also be determined using this technology. It will also help to reduce soil degradation and will help to create better soil-crop environment.

REFERENCES:-

1. Koomans Ronald, Limburg Han , Van der Veeke Steven, October 5, 2022, Soil mapping with drones: The use of gamma-ray spectrometers in airborne surveys, Gim international.
2. McCarthy, C.; Nyoni, Y.; Kachamba, D.J.; Banda, L.B.; Moyo, B.; Chisambi, C.; Banfill, J.; Hoshino, B. Can Drones Help Smallholder Farmers Improve Agriculture Efficiencies and Reduce Food Insecurity in Sub-Saharan Africa? Local Perceptions from Malawi. Agriculture 2023, 13, 1075. https://doi.org/10.3390/agriculture13051075
3. Lagacherie P, Baret F, Féret JB, Netto JM, Robbez-Masson JM. Estimation of soil clay and calcium carbonate using laboratory, field and airborne hyperspectral measurements. Remote Sens. Environ. 2008;112(3):825–835. doi: 10.1016/j.rse.2007.06.014

4. Pu YL, *et al*. Response of the organic carbon fractions and stability of soil to alpine marsh degradation in Zoige, East Qinghai-Tibet Plateau. J. Soil Sci. Plant Nutr. 2020;20:2145–2155.
5. Stenberg B, Rossel RAV, Mouazen AM, Wetterlind J. Visible and near infrared spectroscopy in soil science. Adv. Agron. 2010;107:163–215. doi: 10.1016/S0065-2113(10)07005-7.
6. Azizi K, Garosi Y, Ayoubi S, Tajik S. Integration of Sentinel-1/2 and topographic attributes to predict the spatial distribution of soil texture fractions in some agricultural soils of western Iran. Soil Tillage Res. 2023;229:105681. doi: 10.1016/j.still.2023.105681.
7. Kaya F, Başayiğit L, Keshavarzi A, Francaviglia R. Digital mapping for soil texture class prediction in northwestern Türkiye by different machine learning algorithms. Geoderma Reg. 2022;31:e00584. doi: 10.1016/j.geodrs.2022.e00584.
8. Omondiagbe OP, Lilburne L, Licorish SA, MacDonell SG. Soil texture prediction with automated deep convolutional neural networks and population-based learning. Geoderma. 2023;436:116521. doi: 10.1016/j.geoderma.2023.116521.
9. Shu MY, *et al*. Improved estimation of canopy water status in maize using UAV-based digital and hyperspectral images. Comput. Electron. Agric. 2022;197:106982. doi: 10.1016/j.compag.2022.106982.
10. Gu XH, Wang YC, Sun Q, Yang GJ, Zhang C. Hyperspectral inversion of soil organic matter content in cultivated land based on wavelet transform. Comput. Electron. Agric. 2019;167:105053. doi: 10.1016/j.compag.2019.105053.
11. Ma SL, He BZ, Ge XY, Luo XF. Spatial prediction of soil salinity based on the Google Earth Engine platform with multitemporal synthetic remote sensing images. Ecol. Inform. 2023;75:102111. doi: 10.1016/j.ecoinf.2023.102111.
12. Ge XY, Wang JZ, Ding JL, Cao X, Li X. Combining UAV-based hyperspectral imagery and machine learning algorithms for soil moisture content monitoring. PeerJ. 2019;7:e6926. doi: 10.7717/peerj.6926.
13. Chen SM, *et al.* Prediction of nitrogen, phosphorus, and potassium contents in apple tree leaves based on in-situ canopy hyperspectral reflectance using stacked ensemble extreme

learning machine model. J. Soil Sci. Plant Nutr. 2021;22:10–24. doi: 10.1007/s42729-021-00629-3.

14. Hu J, Peng J, Zhou Y, Xu D, Shi Z. Quantitative estimation of soil salinity using UAV-borne hyperspectral and satellite multispectral images. Remote Sensing. 2019;11(7):736. doi: 10.3390/rs11070736.
15. Qi Song, Xiaohong Gao, Yuting Song, Qiaoli Li, Zhen Chen, Runxiang Li, Hao Zhang, and Sangjie Cai, 2023 Aug 29, Estimation and mapping of soil texture content based on unmanned aerial vehicle hyperspectral imaging, doi: 10.1038/s41598-023-40384-2.
16. Soviany C (2003) Embedding data and task parallelism in image processing applications, PhD Thesis, Technische Univ. Delft.
17. Tetracam (2019) http://www.tetracam.com/Products_PixelWrench2. htm. 2019b, Accessed on 18Agust 2019
18. Tetracam (2016) PixelWrench2 user guide. TetracamInc. 2016
19. Agisoft LLC, St Petersburg R (2016) Agisoft photoscan professional edition. AgiSoft LLC
20. ESRI (2010) ArcInfo user's guide. https://www.esri.com/library/ brochures/pdfs/quick-start-arcgis-online-organizations.pdf, Accessed date: 29 March 2022
21. Heinold S (2007) Tetracam Multi Camera Array (MCA) Installation and Operation
22. Dindaroglu T, Babur E, Yakupoglu T, Rodrigo-Comino J, Cerda A (2021) Evaluation of geomorphometric characteristics and soil properties after a wildfre using Sentinel-2 MSI imagery for future fre-safe forest. Fire Saf J 122:103318
23. Dindaroğlu T (2014) The use of the GIS kriging technique to determine the spatial changes of natural radionuclide concentrations in soil and forest cover. J Environ Health Sci Eng 12(1):1–11
24. Dindaroğlu T, Gündoğan R, Gülci S (2017) Determination of the actual land use pattern using unmanned aerial vehicles and multispectral camera. Int Arch Photogramm Remote Sens Spat Inf Sci 42(4/W6).
25. Jaroslav Šedina, Eliška Housarová & Paulina Raeva (2018): Using RPAS forthe detection of archaeological objects using multispectral and thermal imaging. *European Journal of Remote Sensing.*

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