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Using crowd sourcing and geopositioned images to document near real time rangeland condition

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Abstract
Monitoring rangeland vegetation is essential for sustainable land management, biodiversity conservation, and climate change mitigation. Traditional vegetation monitoring methods often require extensive fieldwork, which can be time-consuming and costly. Crowdsourcing, which leverages the collective power of a large number of volunteers, offers a promising alternative. This study examines the effectiveness of using crowdsourcing to collect geopositioned images for monitoring rangeland vegetation. By engaging herders and pastoralists with smartphones featuring built-in GPS capabilities, a substantial dataset of geotagged photographs from diverse rangelands was amassed. These images were transferred to a central repository when an internet connection was available, ensuring continuous data flow from even the most remote areas. Subsequently, the images were analysed using advanced image processing and machine learning techniques to assess vegetation and ground cover in near real time. Preliminary results indicate that our protocol can provide high spatial and temporal resolution imagery, which complements traditional monitoring methods by offering more immediate and detailed insights. These images also serve as ground truth for supervised classification of large-scale remote sensing satellite scenes. Additionally, this approach enables sampling of inaccessible remote areas while promoting community engagement and environmental awareness among pastoral communities. The necessary steps for implementation are discussed, along with examples from various locations. The findings highlight the potential of crowdsourcing as a cost-effective and scalable tool for rangeland monitoring and management, showcasing its ability to enhance both data quality and stakeholder participation.

Introduction
Vegetation canopy cover is a critical biophysical indicator for assessing rangeland condition. It protects the soil surface and influences key ecological processes such as rainfall infiltration, soil erosion reduction, soil

respiration, sunlight interception, and wind erosion, thus supporting overall ecosystem functionality (Spaeth Jr, 2020; Park et al, 2024). Additionally, vegetation cover is a vital measure of rangeland health, closely correlated with climate conditions (Almalki et al, 2023). Its composition and structure, which directly impact rangeland productivity, are influenced by grazing practices and other human activities (Sanaei et al, 2018).

Assessing changes in vegetation cover is fundamental for understanding the interaction between environmental and climatic conditions, human activities, land-use practices, and natural ecosystems (D'adamo et al, 2021). Monitoring these changes over time provides valuable information that informs effective management planning and promotes sustainable resource utilization (Azarm et al, 2021). Data on vegetation cover changes are crucial for predicting future trends and establishing a long-term framework to enhance decision-making and resource management (Shi et al, 2022). Therefore, the availability of accurate, up-to-date information is essential for supporting effective monitoring, planning, and management efforts in rangeland ecosystems.

However, quantifying ecosystem parameters to track conditions and trends remains challenging, time-intensive, and costly, resulting in limited detailed records for many areas worldwide. To address these challenges, this paper presents a procedure for local scale monitoring that documents rangeland conditions in near real-time. By integrating crowdsourcing, geopositioned digital images, and advanced image processing software, we enable the rapid sampling and recording of vegetation, litter, and soil parameters. VegMeasure®, an image analysis tool developed to monitor vegetation cover over time (Louhaichi et al, 2001; Louhaichi and Hassan, 2018), serves as a component of this process. This approach offers a practical, efficient, and scalable solution for enhancing rangeland monitoring and management.

Methods

The VegMeasure® software offers an efficient and cost-effective solution for estimating rangeland vegetation parameters and conducting non-destructive monitoring. To facilitate data collection, three pastoralists were equipped with smartphones featuring GPS-enabled 16-megapixel digital cameras. Participants received training on proper image acquisition techniques before starting data collection.

Images were captured using a pole-mounted camera to maintain a consistent height, as recommended by Booth et al. (2004) (Fig. 1a). When a pole was unavailable, handheld images were taken at a comfortable height (Fig. 1b). The pastoralists were trained to hold the smartphones vertically to ensure accurate GPS georeferencing during image acquisition. Each pastoralist captured images across their respective rangeland locations, ensuring diverse coverage of vegetation and bare ground conditions. Captured images were uploaded to a designated repository once a Wi-Fi connection was available and were subsequently processed using VegMeasure® software. The software employed a supervised classification method, assigning each pixel in an image to a specific class type based on predefined categories, enabling the classification of different land cover types. While VegMeasure® can classify ground cover into multiple categories, including vegetation, bare ground, rocks, and litter (Louhaichi et al, 2018), this study utilized a simplified two-class system, focusing on vegetation cover and bare ground. Classification accuracy was assessed using the accuracy assessment tool in VegMeasure®, which computes an error matrix and derives the Kappa Index of Agreement to quantify classification reliability. Stratified random sampling was applied, selecting 180 points per class from 50% of the images to validate the accuracy of the classified outputs.

Fig. 1a: Technical staff from Sughd Province - Tajikistan using a pole for taking straight down images.

Fig. 1b: Pastoralist from Rasht valley in Northeastern Tajikistan, taking images using a smartphone.

Results

A total of 180 images, with 60 captured by each pastoralist (which accounted for approximately 70-75% of their total images) in the Rasht Valley, were analyzed after excluding those that were not vertically oriented or were affected by shadows to ensure the quality and consistency of the dataset. The analysis revealed notable differences in vegetation and bare ground cover across the areas managed by the three pastoralists. The first pastoralist's images showed an average vegetation cover of 60%, with values ranging from 50% to 65%, while bare ground accounted for the remaining 40%, ranging from 35% to 50%. The second pastoralist's images exhibited a significantly higher average vegetation cover of 70%, with a range of 59% to 81%, and a correspondingly lower bare ground cover of 30%, ranging from 19% to 40%. In comparison, the third pastoralist's images indicated an average vegetation cover of 53%, with bare ground making up 47%. The classification accuracy of the analysis was consistently high, ranging from 95-99% (Fig. 2 a, b).

Fig. 2a: Straight down image of Tajikistan grassland (before).

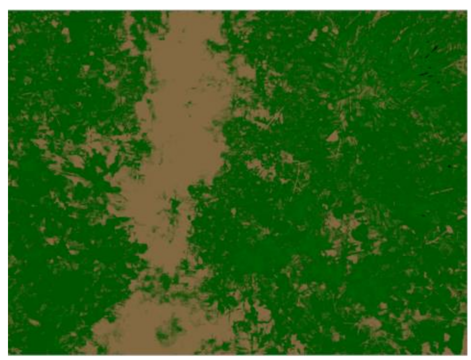

Fig. 2b: Processed image using VegMeasure software (after): plant cover 78.5%, bare ground 21.5%, classification accuracy: 98%

Discussion

The results demonstrate the potential of using readily available smartphone technology, paired with VegMeasure software, for efficient and cost-effective assessment of rangeland vegetation cover in the Rasht Valley of Tajikistan. The variation in vegetation cover across rangelands, where pastoralists graze their animals, highlights the spatial heterogeneity typical of rangelands, particularly in terms of plant cover. This variation emphasizes the need for localized monitoring and tailored management strategies (Bestelmeyer et al, 2019).

This approach offers a significant advantage over traditional methods, as it reduces the labour-intensive and time-consuming aspects of rangeland assessment (Yu and Guo 2021). Additionally, it allows for continuous monitoring over time, enabling the study of both current and past conditions (Hu et al, 2024). Each image captured includes GPS location data, providing a valuable tool for tracking changes in vegetation cover and informing management strategies However, changing weather conditions like snow and rain, uneven rangeland geography, maintaining the phone's level and angle, and issues with shadows and lighting were challenging for pastoralists taking photos.

Despite these challenges, the simplicity of image acquisition—requiring only basic training in proper image capture techniques—makes this approach easily accessible to local communities, empowering them to actively participate in monitoring their rangelands. Furthermore, this participatory approach fosters knowledge sharing and facilitates communication of rangeland conditions to local authorities, which is essential for effective decision-making and sustainable rangeland management.

Conclusions/Implications

Integrating geo-referenced images collected through community networks can play a pivotal role in the sustainable management and restoration of Tajikistan's rangelands and ecosystems. This approach not only has the potential to significantly reduce monitoring costs but also facilitates the generation of detailed datasets critical for tracking site changes and trends over time. It enables seasonal or annual revisits to monitored sites, providing insights into the spatial and temporal impacts of natural and human interventions. Moreover, it standardizes ground cover estimates across sites, overcoming the limitations of traditional visual assessments. Ultimately, this method supports both ecological restoration efforts and the empowerment of local communities.

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References

Almalki R, Khaki M, Saco PM, Rodriguez JF (2022) Monitoring and mapping vegetation cover changes in arid and semi-arid areas using remote sensing technology: a review. Remote Sensing 14(20), 5143.

Azarm H, Bakhshoodeh M, Zibaei M, Nasrnia F (2022) Incorporating land use changes and pastoralists' behavior in sustainable rangeland management: evidence from Iran. Rangeland Ecology & Management 80, 48–60.

Bestelmeyer BT, Burkett LM, Lister L, Brown JR, Schooley RL (2019) Collaborative approaches to strengthen the role of science in rangeland conservation. Rangelands 41(5), 218–226.

Booth DT, Cox SE, Louhaichi M, Johnson DE (2004) Lightweight camera stand for close-to-earth remote sensing. Journal of Rangeland Management 57, 675–678.

D'adamo F, Ogutu B, Brandt M, Schurgers G, Dash J (2021) Climatic and non-climatic vegetation cover changes in the rangelands of Africa. Global and Planetary Change 202, 103516.

Louhaichi M, Borman MM, Johnson DE (2001) Spatially located platform and aerial photography for documentation of grazing impacts on wheat. Geocarto International 16, 63–68.

Louhaichi M, Hassan S (2018) Digital Vegetation Charting: a robust and cost-effective technique for estimating plant cover, leaf litter, and bare ground in grassland areas. International Center for Agricultural Research in the Dry Areas (ICARDA), Beirut, Lebanon. https://hdl.handle.net/20.500.11766/9136

Louhaichi M, Hassan S, Clifton K, Johnson DE (2018) A reliable and non-destructive method for estimating forage shrub cover and biomass in arid environments using digital vegetation charting technique. Agroforestry Systems 92, 1341–1352.

Park JH, Lee SH, Kim YS, Park JW, Lee JM, Park YB, Kim EJ, You YH (2024) Vegetation cover is a crucial key to the success of ecological restoration in the desertified steppe of Inner Mongolia. Ecological Indicators 165, 112241.

Sanaei A, Ali A, Chahouki MAZ, Jafari M (2018) Plant coverage is a potential ecological indicator for species diversity and aboveground biomass in semi-steppe rangelands. Ecological Indicators 93, 256–266.

Shi H, Rigge M, Postma K, Bunde B (2022) Trends analysis of rangeland condition monitoring assessment and projection (RCMAP) fractional component time series (1985–2020). GIScience & Remote Sensing 59(1), 1243–1265.

Spaeth Jr KE (2020) Hydrology and Erosion Processes. Soil Health on the Farm, Ranch, and in the Garden, 85–136.

Yu X, Guo X (2021) Extracting fractional vegetation cover from digital photographs: a comparison of in situ, SamplePoint, and image classification methods. Sensors 21(21), 7310.