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Advanced methods for measuring the nutritional content of grass: integrated TaurusWebs and spectrum analysis

Métodos avançados para medir o conteúdo nutricional da grama: TaurusWebs integrado e análise de espectro

Métodos avanzados para medir el contenido nutricional del pasto: TaurusWebs integrado y análisis espectral

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Abstract
This research aimed to evaluate the effectiveness of advanced methods, specifically the integration of TaurusWebs and spectral analysis, for the accurate measurement of grass nutrient content. Ten soil and grass samples, specifically of the Megathyrsus maximus species, including the common Savoy variety and the Mombasa cv., were collected from an experimental grass crop at the coastal region of Ecuador. Samples were analyzed for total organic carbon (using a BIOBASE elemental analyzer) and protein levels (via standard lab methods). Multispectral drone images (Mavic Air 2S and RedEdge P) were also captured to generate orthomosaics and calculate NDVI, and measure chlorophyll content with an OPTI-SCIENCES CCM-200 device. TaurusWebs software provided real-time digital bromatological analysis. Statistical analysis, including Pearson correlations and Student's T-tests, was performed using Python. Findings indicate a strong correlation between organic matter and grass protein content (r=0.87), suggesting its predictive value for nutritional quality. Conversely, NDVI showed a very low correlation with protein (r=0.04) but a strong link with chlorophyll. Although TaurusWebs protein levels were somewhat lower than laboratory results, the variations were negligible and most likely caused by environmental factors or model constraints with new grass kinds. With all factors considered, the combined method showed potential for locating and classifying regions with greater grass protein concentrations, nearly matching conventional laboratory testing. This demonstrates the prospective contribution of cutting-edge techniques to better forage evaluation and animal production optimization.
Keywords: Forage quality; Spectral analysis; TaurusWebs; Nutrient content; Livestock production.

Resumo
Esta pesquisa teve como objetivo avaliar a eficácia de métodos avançados, especificamente a integração do TaurusWebs e análise espectral, para a medição precisa do conteúdo de nutrientes em gramíneas. Dez amostras de solo e gramíneas, especificamente da espécie Megathyrsus maximus, incluindo a variedade Savoy comum e a cultivar Mombasa, foram coletadas de uma cultura experimental de gramíneas na região costeira do Equador. As amostras

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foram analisadas quanto ao carbono orgânico total (usando um analisador elementar BIOBASE) e aos níveis de proteína (por meio de métodos laboratoriais padrão). Imagens multiespectrais de drones (Mavic Air 2S e RedEdge P) também foram capturadas para gerar ortomosaicos e calcular o NDVI, e o conteúdo de clorofila foi medido com um dispositivo OPTI-SCIENCES CCM-200. O software TaurusWebs forneceu análise bromatológica digital em tempo real. A análise estatística, incluindo correlações de Pearson e testes t de Student, foi realizada usando Python. Os resultados indicam uma forte correlação entre a matéria orgânica e o conteúdo de proteína das gramíneas (r = 0,87), sugerindo seu valor preditivo para a qualidade nutricional. Por outro lado, o NDVI apresentou uma correlação muito baixa com a proteína (r = 0,04), mas uma forte ligação com a clorofila. Embora os níveis de proteína do TaurusWeb tenham sido ligeiramente inferiores aos resultados de laboratório, as variações foram insignificantes e provavelmente causadas por fatores ambientais ou restrições do modelo com novos tipos de gramíneas. Considerando todos os fatores, o método combinado demonstrou potencial para localizar e classificar regiões com maiores concentrações de proteína em gramíneas, quase igualando-se aos testes laboratoriais convencionais. Isso demonstra a contribuição prospectiva de técnicas de ponta para uma melhor avaliação da forragem e otimização da produção animal.
Palavras-chave: Qualidade da forragem; Análise espectral; TaurusWebs; Teor de nutrientes; Produção animal.

Resumen
Esta investigación tuvo como objetivo evaluar la eficacia de métodos avanzados, en particular la integración de TaurusWebs y el análisis espectral, para la medición precisa del contenido de nutrientes en pastos. Se recolectaron diez muestras de suelo y pasto, específicamente de la especie Megathyrsus maximus, incluyendo la variedad común Savoy y el cv. Mombasa, de un cultivo experimental de pastos en la región costera de Ecuador. Se analizaron las muestras para determinar el carbono orgánico total (utilizando un analizador elemental BIOBASE) y los niveles de proteína (mediante métodos estándar de laboratorio). También se capturaron imágenes multiespectrales de drones (Mavic Air 2S y RedEdge P) para generar ortomosaicos y calcular el NDVI, y se midió el contenido de clorofila con un dispositivo OPTI-SCIENCES CCM-200. El software TaurusWebs proporcionó análisis bromatológico digital en tiempo real. El análisis estadístico, que incluyó correlaciones de Pearson y pruebas t de Student, se realizó con Python. Los hallazgos indican una fuerte correlación entre la materia orgánica y el contenido de proteína del pasto (r = 0,87), lo que sugiere su valor predictivo para la calidad nutricional. Por el contrario, el NDVI mostró una correlación muy baja con la proteína (r = 0,04), pero una fuerte relación con la clorofila. Si bien los niveles de proteína de TaurusWebs fueron ligeramente inferiores a los resultados de laboratorio, las variaciones fueron insignificantes y probablemente causadas por factores ambientales o limitaciones del modelo con nuevos tipos de pastos. Considerando todos los factores, el método combinado mostró potencial para localizar y clasificar regiones con mayores concentraciones de proteína de pastos, prácticamente igualando las pruebas de laboratorio convencionales. Esto demuestra la contribución prospectiva de las técnicas de vanguardia para una mejor evaluación de forrajes y la optimización de la producción animal.
Palabras clave: Calidad del forraje; Análisis espectral; TaurusWebs; Contenido de nutrientes; Producción ganadera.

1. Introduction

Global food security is a setting up challenge, emphasizing the critical need to maximize food production resources, particularly within livestock systems that provide crucial meat, milk, and other byproducts for human use (Valdés and Ortiz, 2021; Jurado et al., 2023). To maximize efficiency in these systems, a multidimensional strategy is required, which includes careful consideration of animal density, sanitary conditions, and management procedures, as well as efficient water and energy consumption (Parra-Cortés et al., 2019). Of paramount importance, the nutritional quality of pasture emerges as a critical component, impacting both animal health and performance. Carbon enhances soil fertility and facilitates plant biomass synthesis, increasing livestock production efficiency and contributing to climate change mitigation through atmospheric carbon sequestration (Ramírez et al., 2024).

Despite the crucial relevance of high-quality pasture, nutritional characteristics in Latin America regularly deteriorate owing to poor agroclimatic conditions (Jurado et al., 2023). The variety of production strategies, along with obstacles such as droughts, unexpected rainfall, and irregular soil fertility, make it difficult to continuously produce pastures with a sufficient nutritional profile (Navas and Méndez, 2022). Throughout the continent, huge regions are dedicated to grasslands: Brazil leads with approximately 167 million hectares, followed by Argentina with 73 million hectares, Mexico with around 25 million, and Ecuador with nearly 2 million hectares spread across Andean and Amazonian areas, mainly for supporting native cattle (Fresneda et al., 2024).

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The farming of livestock is an important economic driver in Ecuador, mostly in rural communities where it generates considerable revenue and occupations (Avilés et al., 2022). Ecuador, like other countries of Latin America, confronts significant issues in effectively managing pasture resources (González et al., 2022; Heredia et al., 2022). Producers generally lack suitable instruments for reliably analyzing grass nutritional qualities, instead depending on expensive and unproductive conventional approaches (León et al., 2018). In locations such as Manabí, a lack of information for decision-making within livestock systems can have a substantial influence on farm profitability and sustainability (Miranda, 2019).

Optimal cattle production requires efficient assessment and monitoring of pasture quality (Ramírez et al., 2024). Traditional analytical procedures, such as manual sampling and laboratory analysis, are sometimes costly, time-consuming, and inaccessible to small and medium-sized businesses. By chance, better techniques are evolving to overcome these constraints. TaurusWebs and other technologies provide accurate and non-destructive monitoring of nutritional indicators, greatly lowering costs and time as compared to traditional methods (Ospina, 2023). Also, spectral imaging approaches can correctly evaluate and correlate components like proteins and fibers, supporting real-time decision making (Sinde et al., 2020).

Addressing the drawbacks of conventional methods and leveraging the opportunities presented by emerging technology, it is imperative to employ cutting-edge strategies for precise grass nutrient level determination. Such an approach seeks to elevate livestock productivity and foster the overall sustainability and efficiency of livestock systems through enhanced feed assessment (Gen et al., 2010). Thus, the objective of this research was to evaluate the effectiveness of advanced methods, specifically the integration of TaurusWebs and spectral analysis, for the accurate measurement of grass nutrient content.

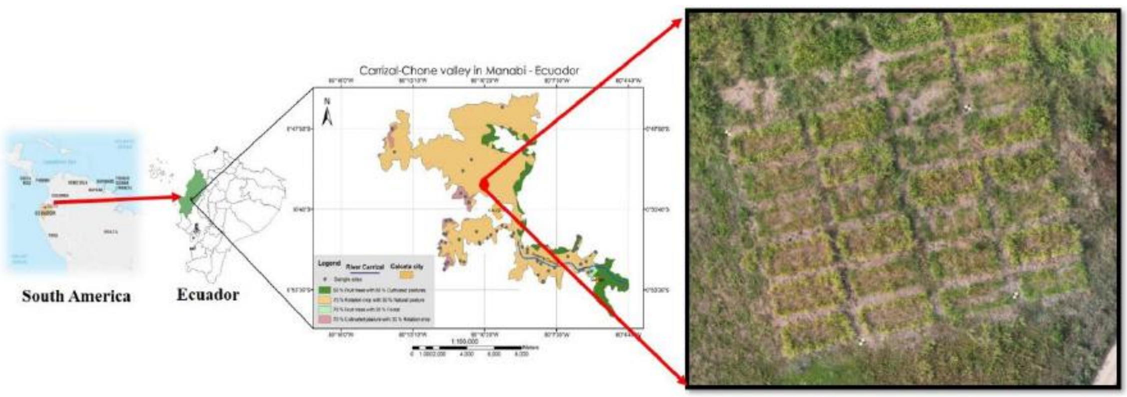
2. Methodology

The research followed a mixed-methods, quantitative approach, doing research in both lab and field settings. To evaluate the data, statistical analysis was essential. Methodological guidelines were taken from sources such as Bekman & Costa Neto (2009) and Pereira et al. (2018). A thorough and in-depth investigation was made possible by this dual setup.

2.1 Study Area

The study was carried out in an area of a grass crop in the Ciudad de Investigación, Innovación y Desarrollo Agroproducitvo (CIIDEA) at an altitude of 50 meters above sea level. The study area is located at the Escuela Superior Politécnica Agropecuaria de Manabí Manuel Félix López (ESPAM MFL) (Figure 1). The topography is sloping, with clayey-silty soils that are highly degraded by solar radiation, caused by high temperatures.

Figure 1 - Location of the grassland cultivation area under high water stress in CIIDEA, located in Bolivar Canton.



Source: Google Earth and ArcMap data.

2.2 Soil sampling and post-processing

Ten sampling points were selected in the study area. At each grassland sampling point, soil samples were collected to a depth of 0-10 cm during October 2024. The soil sample preparation process was: drying at 60 degrees for 72 hours in an oven. Each sample was ground and sieved to a 2 mm sieve to standardize the soil samples. Soil samples were stored in 50g plastic containers in the laboratory of ESPAM MFL.

2.3 Organic carbon

The total soil carbon content was quantified from 10 grams of soil, which were transferred to a flask with 25 ml of distilled water added. The mixture was stirred for 15 minutes using a magnetic stirrer to homogenize the soil particles. The solution was then centrifuged at 2,500 rpm for 20 minutes to promote particle separation.

After the magnetic stirring process, the sample was filtered through plastic tubes designed to retain solid particles, allowing the recovery of the remaining liquid. Finally, after centrifugation, the remaining solid particles were separated through a second filtration process to obtain only the liquid phase, which will be used to determine the soil's carbon content.

Carbon was measured using the BIOBASE BK-TOC2000 and BK-TOC3000 elemental analyzer (*BIOBASE CARBONO*) (*Total Organic Carbon Analyzer BK-TOC2000 and BK-TOC3000*) which allow measuring total carbon in water and soil samples.

2.4 Obtaining biomass to determine grass protein levels

The study area was delimitated to determine and compare the protein levels of two varieties of grass *Megathyrsus maximus*: the common Savoy variety and the *Mombasa cv*.

The grass sample preparation process consisted of drying at 70 ° C for 72 hours in an oven. Each sample was ground and sieved. The grass samples were stored in 50g plastic containers in the laboratory of the ESPAM MFL.

2.5 Images of the study area

Mavic Air 2S Drone was used (Drone Forensics: A Case Study On DJI Mavic Air 2, 2022) for image capture. The flights were carried out, following the flight plans that were programmed using the Harmony drone application (Macdonald et al., 2020). The flight conditions were configured at a flight height of 20 meters, a spatial resolution of 2.56 cm^2 per pixel, an overlap of 80% and an aircraft speed of 4.5 ms^{-1}. The ortho mosaics were generated in the Pix4D Mapper pro® software (Pix4D SA, 2022), while the map creation was done using ArcMap 10.8® software (Caso Osorio, 2010).

2.6 Spectral images

RedEdge P multispectral camera with spectral bands in green, red, blue, red edge, and near-infrared (NIR), was used; altogether to a 5.1-megapixel panoramic panchromatic sensor. This camera was coupled to an Unmanned Aerial Vehicle (UAV) adapted to the Matrix 350 drone. Flights took place between 2:40 p.m. and 3:30 p.m. Before each flight, images were captured from the calibration reflective panel to perform radiometric corrections and minimize distortions derived from the electromagnetic response of the ground and atmospheric phenomena. Flight plans were programmed using the DJI application for equipment control, setting a flight height of 30 meters, a spatial resolution of 2.56 cm^2 per pixel, 80% overlap, and an aircraft speed of 6 ms^{-1}. The orthomosaics were generated using the aforementioned software. Subsequently, the images corresponding to the sampled points were cropped and the NDVI (Normalized Difference Vegetation Index) spectral index was calculated using the same software and displayed in ArcMap 10.8®.

2.7 Vegetation index

The data was obtained from previously captured images and processed using the appropriate software, which generated spectral images that included the near-infrared (NIR) and red visible spectrum (RED) bands. From this information, NDVI was calculated formula (1).

$$NDVI = \frac{NIR - Red}{NIR + Red} \quad (1)$$

2.8 Chlorophyll

The determination of the amount of chlorophyll stored in the grass in each plot was carried out using the OPTI-SCIENCES CCM-200 device. This device is an improved version of the well-known CCM-200 model. It is designed with an enlarged measuring area that allows for averaging of the obtained signal. This optimized design provides more reliable measurements by considering minor structural variations in the grass, which can influence the repeatability and accuracy of the results when using smaller sampling areas (Accurate, 2012).

2.9 TaurusWebs

This software, designed for livestock farming, increases organization, productivity, and profitability in dairy, fattening, breeding, or dual-purpose production systems. This program allows for real-time digital bromatological analysis, including the determination of protein percentage, neutral detergent fiber percentage, acid detergent fiber percentage, and net lactation energy, of pastures in real time. Its implementation represents a cost-effective and rapid alternative to traditional methods, such as those used in laboratories with the NIRS test or the wet chemical test. Furthermore, the algorithm has shown a confidence level of 93% compared to benchmark laboratories, positioning it as one of the most accurate and reliable tools available on the market (Rica & Salvador, n.d.).

2.10 Statistical analysis

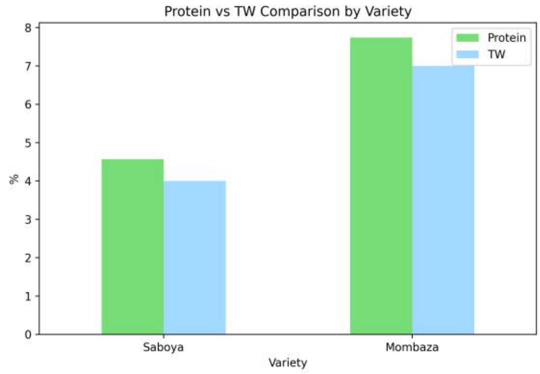
An exploratory analysis of descriptive data and Pearson correlations were performed to determine which variables were most strongly associated with each other. A Student T-test was also used to assess the differences between the values of the two groups (laboratory data vs. digital data). All analyses were performed using the Python platform.

3. Results and Discussion

3.1 Protein content: lab data vs. TaurusWebs

It was observed that protein values tend to be slightly higher than those generated by TaurusWebs for the Saboya and Mombaza varieties (Figure 2). According to Castillo et al. (2025), these minimal differences are due to the fact that platforms based on predictive models largely depend on calibrated databases that may have limitations when applied to new varieties or environmental conditions not originally contemplated, therefore the laboratory analysis shows a more punctual success. In the Saboya variety, it is observed that the protein value slightly exceeds that estimated by TaurusWebs, while in Mombaza both data are higher but maintain the same trend, this coincides with Díaz et al. (2023) who indicates that spectral models tend to present more precision in varieties with more marked nutritional characteristics.

Figure 2 - Comparative analysis of grass protein content: laboratory determination and TaurusWebs prediction by variety.



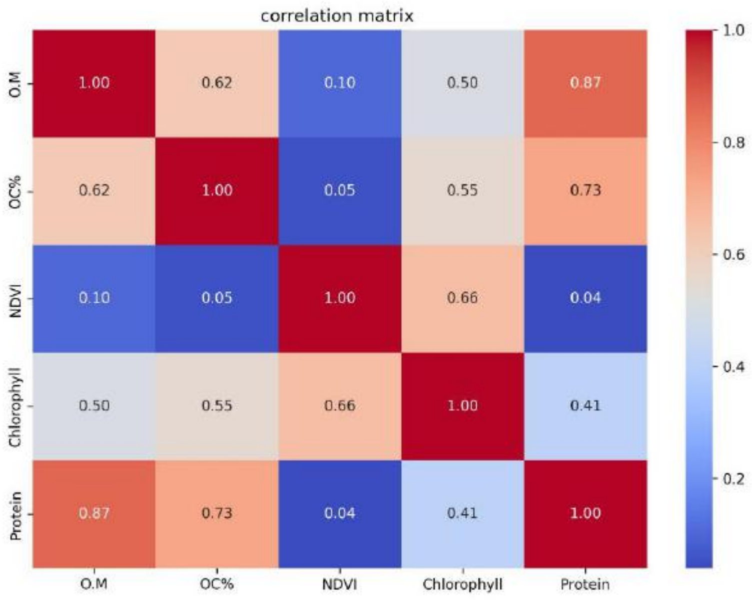
Source: Research data.

According to this, Pereira et al. (2022) argue that the combined use of near-infrared reflectance spectroscopy (NIRS) and digital platforms facilitates the identification of varietal differences, as evidenced in the graph. This means that the integration of spectral methods with digital platforms improves the accuracy of nutritional estimates and allows for more informed agronomic decisions about forage. In line with the above, Castillo et al. (2025) technological advances in forage evaluation allow for a certain reduction in dependence on conventional laboratory analysis, thereby promoting precision agriculture with a technological focus.

3.2 Correlation matrix

The data show a strong correlation between organic matter (OM) and protein content (r = 0.87), indicating that soils with higher organic content tend to produce grasses with higher nutritional value (Figure 3). According to Rodríguez et al. (2024), organic matter improves the availability of essential nutrients for plant growth, particularly nitrogen, which is key to protein synthesis. Similarly, the percentage of organic carbon (OC%) showed a moderately high positive correlation with protein (r = 0.73); therefore, this indicator can also be considered a predictor of pasture nutritional quality. In contrast, the NDVI showed a very low correlation with protein content (r = 0.04); that is, this vegetation index does not adequately reflect the nutritional quality of forage, especially in terms of protein. In this sense, Núñez et al. (2021) argue that NDVI is more effective in estimating biomass than chemical composition, on the other hand, chlorophyll showed a moderate correlation with protein (r = 0.41) this condition was addressed by authors such as Baccarrillo et al. (2021) and Molina et al. (2024), who indicate that although chlorophyll is related to photosynthetic activity, its direct link with protein content may vary depending on the type of grass and environmental conditions.

Figure 3 - Pearson correlation matrix of the variables analyzed in the study.

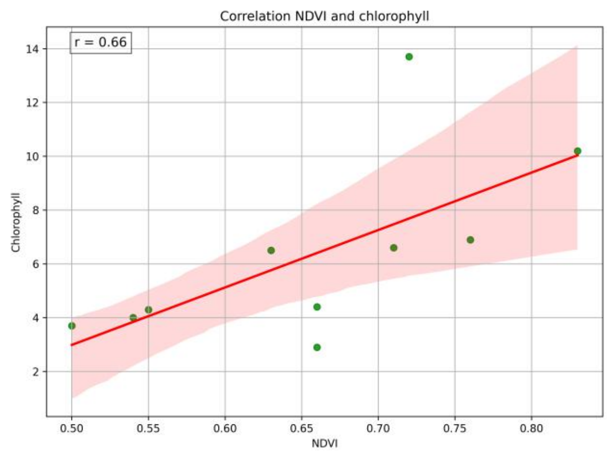


Source: Research data.

3.3 Correlation between NDVI and Chlorophyll

This relationship (Figure 4) is due to the fact that NDVI is influenced by the absorption of radiation in the red and the reflectance in the near infrared, phenomena that are directly associated with the concentration of chlorophyll in the leaves (Molina et al., 2024). However, this correlation is not perfect, because NDVI can also be affected by other factors such as canopy structure, soil moisture and environmental conditions (Núñez et al., 2021). Thus, while Sánchez et al. (2022) is a useful tool to estimate biomass and vigor trends, it has limitations in accurately predicting chlorophyll content, especially under high concentration conditions where it tends to saturate. Recent studies such as that of López et al. (2023) suggest that more specific indices, such as CIred-edge, can offer better sensitivity to chlorophyll, allowing better discrimination in high plant density scenarios, demonstrating that the relationship between NDVI and chlorophyll is consistent, but not definitive, so its interpretation must be complemented with other spectral techniques that allow obtaining more precise estimates of the nutritional status of the grass.

Figure 4 - Correlation between chlorophyll and NDVI.

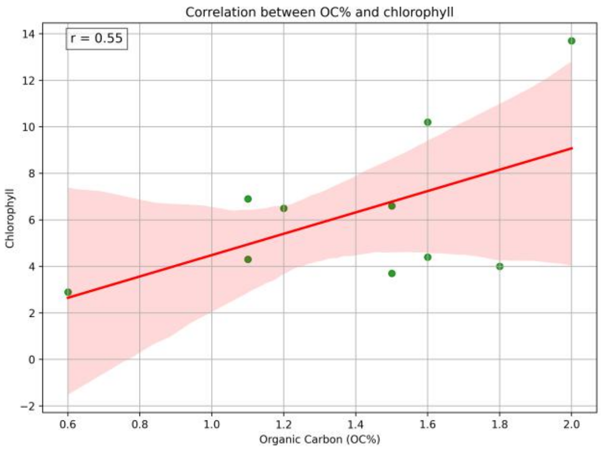


Source: Research data.

3.4 Correlation between OC% and Chlorophyll

It is evident that at higher levels of organic matter in the soil, there is a tendency to find higher concentrations of chlorophyll in plants (Figure 5). This link is based on the fact that this matter is an essential source of nutrients and improves the physical-chemical properties of the soil, this favors the availability of nitrogen and other essential elements for the synthesis of chlorophyll (Molina et al., 2024). However, this correlation is not as strong as in other relationships, which can be explained by the influence of other factors, such as soil structure, aeration and microbial activity, which also intervene in the dynamics of chlorophyll (Núñez et al., 2021). In cases such as that reported by Baccarillo et al. (2021), they indicate that an increase in OC% does not always produce an increase in chlorophyll, especially in soils where pH or salinity restrict nutrient assimilation. That is to say, the effect of organic matter on chlorophyll depends on the interaction with other elements of the soil-plant system.

Figure 5 - Correlation between chlorophyll and OC.



Source: Research data.

4. Conclusion

It should be emphasized that in seasons of extreme drought, it is important to be more efficient in selecting locations for grass cuttings or other environments for grazing livestock.

This technique has demonstrated that the technology developed and validated in different environments has a high potential for achieving stratification in areas with higher levels of grass protein, as in this case study. Similar values were obtained through analogous processes such as those in laboratories and compared to the detection of the same protein levels with spectral cameras and RGB-only images. Reaching an important efficiency in cases extremes of drought.

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