

Classification of *Cynodon* spp. grass cultivars by UAV

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Abstract — *Traditional methods for estimating biomass in pasture frequently use destructive methods with high demand for time, resources and labor. The development of models for automated estimation of biomass and leaf area index, particularly from images captured by Unmanned Aerial Vehicle (UAV), saves resources and helps the adoption of anticipatory measures in the management of the experimental area. The objective of this study was to create a technical feasibility study for the use of UAV in the estimation of biomass, forage canopy height, and general conditions of *Cynodon* grass in plots, using volume and vigor by the radiometric and morphometric approach, the NDRE index, and digital terrain (DTMs) and digital surface (DSMs) models compared to scores by the specialist in the field. Visible (RGB), red edge (RedEdge) and near infrared (NIR) imaging cameras were used for continuous monitoring of the experimental area, of approximately 3,800 m², located at the José Henrique Bruschi Experimental Field (CEJHB), in the municipality of Colonel Pacheco, Minas Gerais, Brazil. After UAV imaging, we selected nine *Cynodon* spp. clones that showed greater vigor based on the data from the field plots and data obtained by UAV and classified using the method to estimate the vegetation vigor index (VVI) and classified by natural breaks in GIS.*

I. INTRODUCTION

Traditional methods for evaluating plants in the field aiming at genetic improvement, attribution of vigor scores and estimation of biomass frequently use destructive methods with high demand for time, resources and labor. In addition, these laborious procedures in the field can cause accuracy errors and not allow for a global assessment of the experimental area regarding phytosanitary issues, pests and diseases, as well as early mineral nutrient deficiencies.

The emerging and evolving technology in aerial photogrammetry survey with unmanned aerial vehicles (UAV) provides countless applications in infrastructure, transport and agricultural research on a daily basis. The ease, speed and versatility in acquiring data, images and

metrics about targets on the Earth's surface allow highly efficient routine and interpretation activities in the field. The small UAV with cameras and multispectral sensors are now added to the new technologies in remote sensing and geoprocessing. These devices facilitate aerial surveys in the detection of biophysical variations in the field with frequency defined by the user and according to the phenological cycle, enabling monitoring of stresses linked to the water condition or pest infestation, in the herbaceous, shrubby or arboreal strata [1, 2, 3, 4].

Genetic selection, phenotyping, and the measurement of agronomic parameters in forages were previously carried out with multiple equipment and demanded a permanent team in the field. This work can now be done with orthophotos by cameras equipped with optical sensors, using scheduled UAV flights, without removing

forage for biomass estimates, for example, even under stress conditions [5, 6, 7]. However, this task must be carried out with safety and statistical significance, hence, several experimental surveys and tests must be performed to ensure that the UAV photogrammetric remote sensing data can support or even replace the cutting of forage clones and laboratory and field measurements.

The analyses and field tests with the UAV flights are based on surveys of geodetic GPS control points, with high accuracy and definition of transformations in the GIS (Geographic Information System) for estimates in the plots of *Cynodon* spp. grass.

Vegetation indices play an important role in pointing out forage stress phenomena [8, 9, 10, 11]. These trials used the vegetation indices described by the equations below:

$$NDVI = \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + \rho_{red}} \tag{Eq. 1}$$

$$VARI = \frac{\rho_{Green} - \rho_{Red}}{\rho_{Green} + \rho_{Red} - \rho_{Blue}} \tag{Eq. 2}$$

$$GLI = \frac{(2 \rho_{Green} - \rho_{Red} - \rho_{Blue})}{(2 \rho_{Green} + \rho_{Red} + \rho_{Blue})} \tag{Eq. 3}$$

$$CI_{green} = \left(\frac{\rho_{nir}}{\rho_{green}} \right) - 1 \tag{Eq. 4}$$

$$NDRE = \frac{\rho_{nir} - \rho_{rededge}}{\rho_{nir} + \rho_{rededge}} \tag{Eq. 5}$$

Where ρ_{Green} , ρ_{Red} , ρ_{Blue} , $\rho_{rededge}$ and ρ_{nir} are the spectral bands referring to the channels of the green, red, blue, red edge and near-infrared (NIR), respectively.

The indices NDVI (Normalized Difference Vegetation Index) [8], VARI (Visible Atmospherically Resistant) [9], GLI (Green Leaf Index) [10], CI_{green} (Green Chlorophyl Index) and NDRE (Normalized Difference Red Edge) [11] were used to obtain maps that indicate the stresses relevant to phytosanitary problems, mineral deficiency, pest infestations, among others, in several experimental treatments applied to clones of *Cynodon* spp. from the Embrapa's genetic improvement program.

Image overlay and altimetric information, digital terrain (DTMs) and digital surface (DSMs) models are produced using stereoscopy, and thus it is possible to obtain altimetric and volumetric information and to determine the volume of plant biomass. Combined information on vegetation indices and forage volume gave

rise to a multicriteria and method approach to estimate the forage vigor, taking radiometry and morphometry/volumetry into account, in order to unite the spectral response with the height or volume of the plants.

From the data on forage mass volume (m^3) in combination with the vegetation indices, it is possible to estimate a vigor measure by the sum of the anomalies of values around the mean, which are standardized by the deviation standard, in order to rank the experimental forage plots, in the face of the scores visually assigned in the field. The selection of the vegetation index involves observing the contrast in the histogram and the ability or numerical precision to distinguish existing variations in the vegetation. The VARI index was developed to take into account the reduction of possible influences of atmospheric constituents by subtracting the spectral band referring to the blue channel in the denominator of Equation 1. The GLI index (Equation 2) has been used to distinguish between photosynthetically active vegetation and dry vegetation with soil exposure.

The NDVI index was originally developed to enhance the herbaceous-shrub vegetation, but it becomes saturated in dense vegetation, while NDRE allows the distinction of nuances between forages with different vigor and the noise represented by the soils. The CI_{green} enhances important aspects of green vegetation, which often does not occur effectively when the vegetation reflects a lot, or significantly, in blue or red.

The objective of this study was to create a technical feasibility study for the use of UAV in the estimation of biomass, forage canopy height, and vigor of plots of *Cynodon* grass and, thus, to develop a method that associates vegetation indices, height and volume of plants to estimate the vegetative vigor of cultivars.

II. MATERIALS AND METHODS

The study was conducted at the José Henrique Bruschi Experimental Field located in Coronel Pacheco (MG). The aerial surveys were carried out using a flight plan for the Inspire 1 drone, aiming at high accuracy using geodetic GPS control points collected in experiments of *Cynodon* spp. clones (Figure 1). Field trials were carried out with the indices VARI, GLI, CI_{green} , NDVI and NDRE with a Sentera™ multispectral camera in the pasture plots.

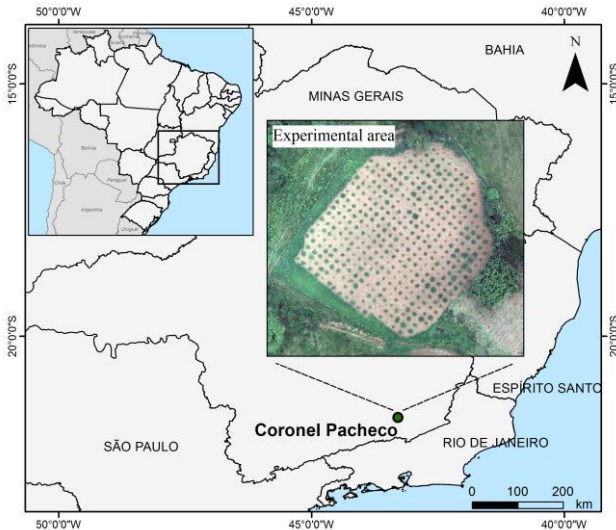


Fig. 1: Location of the experimental area

The method used was developed for the use of UAV with stereoscopic imaging, forage height and volume, as well as spectral response and vegetation indices combined with field survey data, as well as the estimation of an indicator of vegetative vigor in GIS. Using descriptive analysis and the Jenks Natural Breaks Classification in GIS, the superior class was defined with the best combination of vegetation and volume index for the plots of *Cynodon* spp.. The cultivars in this study are mostly derived from hybridization between *Cynodon nlemfuensis* and *Cynodon dactylon*. This method aims to build a differential in the estimates of agronomic correlations, aiming to replace the interpreter's perception in determining grass vigor, which may vary according to the technician's knowledge and experience.

Therefore, this method developed for the use of on-board equipment will be able to standardize the estimates, using an automated procedure and providing image processing using a multi-criteria approach, since it is based on several layers of data related to grass vigor, fresh weight, technician's score, vegetation index, and forage volume (m³).

Empirically, all classes of vegetation indices mentioned, VARI, GLI, CIgreen, NDVI and NDRE were estimated. Thus, in virtue of the characteristics of greater accuracy in the differentiation and details revealed in the vigor of herbaceous vegetation with the hyper-resolution cameras, we used the NDRE index (Equation 5) to apply the method. Therefore, the equation from the data collected is as follows:

$$VVI = \left(\frac{V - \bar{V}}{\sigma_V} \right) + \left(\frac{N - \bar{N}}{\sigma_N} \right) \tag{Eq. 6}$$

Where: VVI is the indicator of vegetative vigor of the experimental plots; V is the mean plot volume and N is the mean NDRE for each plot, \bar{V} is the mean volume for the entire set of plots and \bar{N} is the mean NDRE for the whole set; both σ_V and σ_N are estimates of the volume and the NDRE standard deviation, respectively, for the experimental plots.

Thus, a method was developed that estimates the sum of standardized anomalies between the volume and vegetation index for the set of grass plots, and from the results, the best scored plots were selected, compared to the use of vegetation index alone, and comparing them to the technician's scores, which ranged from 0 to 5.

This method was used in an experiment in the genetic improvement program of the genus *Cynodon*, in the augmented block design according to Federer. The experiment consisted of 8 augmented blocks, each block with 48 non-common treatments and two controls (common treatments Tifton 85 and African star-grass), with the exception of the last block, which consisted of 47 non-common treatments, added to the two common treatments, totaling 399 plots identified by number. At the time of cutting, the plots were scored for vigor, height was measured, and fresh matter of each plot was weighed.

The objective of this study was to create a technical feasibility study for the use of UAV to estimate the correlation of fresh matter production, forage canopy height and vigor of *Cynodon* spp. in the experimental plots. Vegetation index and volume were used through the radiometric and morphometric approach by NDRE index and GIS operations using the digital terrain model (DTM) and digital surface or elevation model (DSM) to derive an anomaly index directly related to vegetative vigor. Visible (RGB), red edge (RedEdge) and near infrared (NIR) imaging cameras were used for continuous monitoring of the experiment conducted at the José Henrique Bruschi Experimental Field (CEJHB), in Coronel Pacheco-MG. The study incorporates a standard procedure in the execution of surveys, with flight planning in the equivalent area and surroundings, due to the need for information outside the limits of the area of interest, in addition to the need to establish a series of parameters regarding the configuration of the FieldAgent™ system used for the UAV (Figure 2).



Fig. 2: Experimental area (A) and configuration of the FieldAgent™ system for UAV flight planning (B)

III. RESULTS AND DISCUSSION

Consistent with the planning of the UAV imaging operations, an accurate flight was performed. Weather conditions were considered, such as wind speed, rainfall, etc ..., favoring good sun light, necessary to standardize the surveys in the experimental areas. One of the most important phases, the pre-survey, consisted of the marking of geodetic control points, which was essential for good final accuracy. From these points, a GSD (Ground Sample Distance) of 2.6 cm on the ground and excellent positional accuracy was obtained, allowing for image overlapping with the same experiment in future flights.

After image processing, by stereoscopy and resampling to 15 cm, DTM and DSM were determined with the altimetric and volumetric estimation of the plots by the difference between the models, selecting the NDRE as the most suitable vegetation index to estimate vigor compared to the other indices tested (Figure 3). From the correlations between the classification of the clone fresh weights in the plots, the scores, the NDRE and the volume, a comparison parameter was established based on a ranking of clones with the best score. This score, obtained from the vigor measurements, led to the construction of a ranking, from

which the best forages in terms of vegetative status, size and vigor were selected.

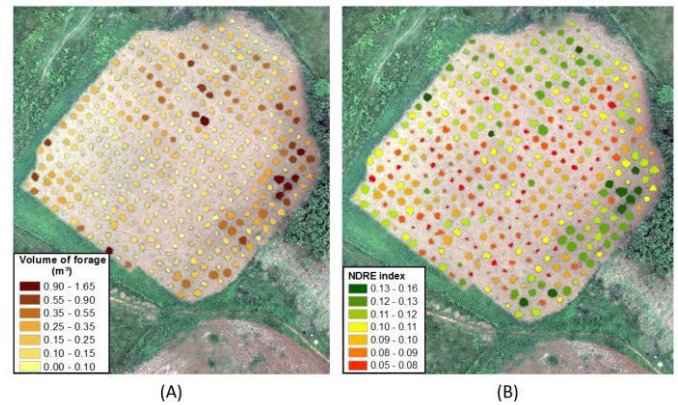


Fig. 3: Map generated from the forage volume (A) and NDRE indices (B)

The NDRE by itself did not provide a good correlation of the scores and fresh weight, according to the data in Table 1 (scores assigned are in parentheses and the letter T represents the control, which is Tifton grass cv 85). It is noted that without all the parameters, which would include the volumetric information (DTM - DSM), the Tifton plots appear in this classification, even if the control grass is used for comparison with the treatments applied to forages in genetic improvement. Thus, the multicriteria approach, which recommends the crossing of layers of information, resulted in a better correlation, and, therefore, the most appropriate selection of these forages. Table 1 also shows the classification of plots using the VVI, which took into account the sum of standardized anomalies between volume and NDRE for the set of *Cynodon* spp. plots.

Table 1. Ranking of forages in the experimental plots by NDRE and VVI

Classification							
NDRE				VVI			
Rank	Nu Plot	Score	Fresh Weight (kg)	Rank	Nu Plot	Score	Fresh Weight (kg)
1st	T 385	4.0	1.38	1st	269	5.0	3.10
2nd	T 68	5.0	3.60	2nd	305	4.5	2.44
3rd	T 270	4.0	2.04	3rd	268	5.0	2.64
4th	305	4.5	2.44	4th	265	5.0	2.68
5th	206	4.0	1.60	5th	277	5.0	2.44
6th	T 213	3.5	1.38	6th	319	5.0	1.50
7th	T 309	4.0	1.45	7th	68	5.0	3.60
8th	265	5.0	2.68	8th	309	4.0	1.45
9th	269	5.0	3.10	9th	3	3.0	1.71

^TTifton cv 85.

Figure 4 illustrates the geographical distribution of the plots with the results of the method used, as well as the classification of the forages, considering the 9 best ranked by the Jenks Natural Breaks Classification, which is highlighted in dark green.

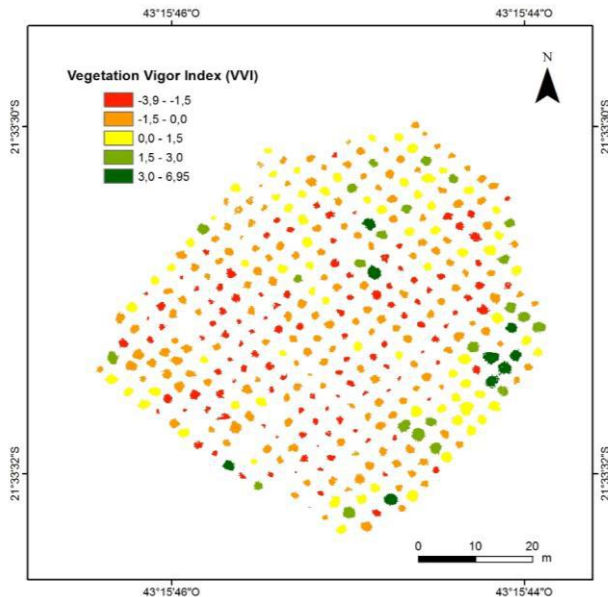


Fig. 4: Map generated using NDRE and measurement of forage volume

IV. CONCLUSION

The UAV provided, in a first approach, a fast and efficient capture of information of the plots in the field by remote sensing, and, through the application of the radio-morphometric approach and the VVI method, a standard was established in the estimates of agronomic parameters for the genetic improvement of *Cynodon* spp. clones. This can greatly contribute, for example, to high-throughput phenotyping in plant breeding programs. This probably constitutes a new knowledge frontier for applications in aerial photogrammetric surveys and extracting of biophysical parameters in crops, phytosanitary issues, and anticipation of stresses that may involve water, mineral nutrition, or entomological aspects. Applications in infrastructure and exploratory mapping will emerge with more strength as the UAV becomes popular in academia and farming.

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