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Monitoring of eucalyptus sprouts control using digital images obtained by unmanned aerial vehicle

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ABSTRACT
This study evaluated the effectiveness of chemical control for eradicating eucalyptus sprouts using images obtained with Unmanned Aerial Vehicle (UAV). The study was carried out in eucalyptus plantations in Itabela, BA, in replanting areas during pre-planting application of herbicide. Aerial images obtained by a UAV were used to evaluate the effectiveness of the herbicide application for sprouts control. After the images were acquired, they were processed to calculate the normalized difference vegetation index (NDVI) and submitted to a supervised classification to quantify the percentage reduction of sprout green matter. The percentage data were submitted to analysis of variance and the means were compared by Tukey test at 5%. The differences, both visual and average percentages were observed only during the evaluation period with no evident effect of the treatments on sprout control. The images provided by the UAV allowed to monitor and identify visually the plots where biomass reduced or increased and to evaluate the effectiveness of chemical control of eucalyptus sprouts, indicating areas where it was nonexistent, partial or total.

KEYWORDS
Geoprocessing; spraying; precision silviculture

Introduction

The forestry sector is an important branch of the Brazilian economy. In the last year, 91% of the wood produced for industrial purposes in Brazil was extracted from planted forests, contributing significantly to reducing deforestation throughout the country (IBÁ - Indústria Brasileira De Árvores, 2017). These data demonstrate that both the current forest economy and environmental sustainability are completely dependent on forestry stability and subsistence (Ruza et al., 2017).

The growth of forestry, led by large companies in the pulp and paper segment, is a vector of transformation and diversification of the agricultural profile of Bahia (De Carvalho & Bajay, 2006). According to these authors, this sectoral development adds

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and contributes to the productive matrix of the state, reducing the instability of the agricultural sector and favoring the progress of forestry activities.

In the midst of unfavorable economic scenarios in Brazil, another factor indicating the importance of the forestry sector is the growth of the sectoral gross product (GDP) in 2015. In that period, according to the balance sheet presented by the Brazilian Tree Industry (IBÁ, 2017), the GDP of the Brazilian forestry sector reached 69.1 billion reais, an increase of 3.0% over the previous year, surpassing other sectors, such as agriculture and services.

In the eucalyptus cultivation system, when choosing to reform the plantation, the elimination of sprouts by either mechanical or chemical methods is of the utmost importance. This activity does not only aim to eradicate the aerial part (sprouts) of the plant, but also to eliminate the possibility of new sprouts (Tibúrcio, 2014). Currently, the chemical control using herbicides is the most common while mechanical control is used only in situations where the chemical does not have the expected efficacy.

When chemical weeding is used to control sprout, it is necessary to monitor the plants over time to evaluate the efficacy of chemical control while guiding the decision-making process on the need for new applications or adopting a new methodology for sprout control. The monitoring process is usually performed by a field team, through random samplings to identify controls. At this stage, a significant amount of information is lost due to the impossibility of evaluating the plot, and the determinations made by sampling are often inefficient.

Therefore, new technologies based on a precision forestry concept that prioritize a strategic model capable of managing the quality control of forestry processes are being used to collect and analyze spatial data for each operational activity regarding forest interventions (Vetorrazzi & De Ferraz, 2000). Currently, Unmanned Aerial Vehicles (UAVs) are being used in the forestry sector, mainly to optimize forest survival indexes, since they allow large sample coverage, reduction of operational costs and accuracy of information (Ruza et al., 2017).

Monitoring of planting failure and sprout control in high stem management systems are two activities with great potential for using UAVs. However, further testing is still necessary to validate the fundamentals and determine with certainty the effectiveness of the tool under these conditions (Terezan, Bernardi, & Silva, 2014).

Despite using UAVs in some forest operations, there is still a certain degree of difficulty for generating automated data, especially in activities concerning replanting. A major challenge is to establish a standard procedure for extracting the features and information of interest from the orthomosaic images obtained using UAVs (Silva, Souto, Duarte, Bicho, & Sabadia, 2015).

In view of the above, this work aimed to evaluate the effectiveness of chemical control for eradicating eucalyptus sprouts using images provided by an unmanned aerial vehicle (UAV).

Material and methods

The study was conducted in eucalyptus plantations located in Itabela (16°34′19” S and 39° 33′33” W) in the most southern region of Bahia, Brazil.

The regional climate is classified as Af, humid tropical, with precipitations throughout the year (Alvares, Stape, Sentelhas, Gonçalves, & Sparovek, 2013). The average annual rainfall in the region is 1100 mm, with temperatures varying between 23ºC and 27ºC. The soil of the experimental plots was classified as Yellow Latosol Dystrophic, according to the Brazilian Soil Classification System (Santos et al., 2013).

The studies focused on evaluating the efficacy of herbicide application in replanting areas to control eucalyptus sprouts up to 75 cm tall during the pre-planting stage. The plants were spaced 5.0 m between rows and 2.40 m between sprouts (hybrid clones of Eucalyptus urophylla and Eucalyptus grandis). At the time of experiment implementation, the height and width of the crown were measured in the middle third of 100 sprouts randomly sampled in each plot, to characterize the area. At the time of application, the average height and width of the sprouts were 1.57 and 1.27 m, respectively.

The application was carried out in five plots (TAL35, TAL40, TAL41, TAL43 and TAL44) of different sizes (areas, in ha), which were considered as sample units of the different treatments (T01, T02 and T03). These treatments consisted of different products and dosages, namely: a) T01: Scout® herbicide with 4 kg.ha^{-1}, in ammonium salt of glyphosate; b) T02: Scout® herbicide with 4 kg.ha^{-1} + 100 ml.ha^{-1} Taiyô foliar fertilizer; c) T03: Scout® herbicide with 4 kg.ha^{-1} + 100 ml.ha^{-1} Taiyô foliar fertilizer + 100 L.ha^{-1} Finale herbicide, in glufosinate ammonium salt. All three treatments were applied in each plot; the experimental parcels were distributed according to plot sizes, allowing a minimum of 65 sprout rows.

Spraying was carried out in November 2016 using a self-propelled sprayer John Deere, model 4630E, with 165 hp nominal power, 6 cylinders, and 6.8 L total displacement. The spray system consisted of a 2270 L reservoir, a 265 L rinse tank, and hydraulic stirring. The spray bar had full hydraulic control, length and height of 24.3 m and 0.38 m to 1.93 m, respectively, but the bar height varied between 1.50 and 1.80 m during application due to uneven sprouts. The application was carried out in the sprout rows at approximately 6.5 km.h^{-1}.

The pressure during application was 3.0 bar with a flow rate of 1.18 L.min^{-1}. The spray nozzles used had flat air induction of fan type, AIUB85-03 model, and spaced 50 cm apart.

The climate parameters such as temperature, relative air humidity, and wind speed were monitored during application every 30 minutes by a weather station near the plots. The average temperature, air relative humidity and wind speed measured were 28°C, 75.6%, and 6.8 km.h^{-1}, respectively.

The effectiveness of the herbicide application for sprout control was evaluated from the aerial images provided by an Unmanned Aerial Vehicle (UAV). The equipment used was the eBee-Ag, by SenseFly, equipped with a Canon camera, S110 - NIR model. The flights took place in November (pre-application of treatments) and December 2016 (30 days after treatment application) and in January 2017 (60 days after treatment application). The images were obtained by the lateral overlap of 65% and longitudinal of 75%, totaling approximately five images per hectare. During the flights, the UAV average displacement speed was 12.5 m.s^{-1}, at 143 m average altitude, ensuring a Ground Sample Distance (GSD) of at least 5.0 cm.

The Canon S110 NIR used for image acquisition has 12 megapixels resolution, 7.44 X 5.58 mm sensor, 1.86 µm pixel density while providing data on green, red and NIR bands, it generates RAW files that can be post-processed according to the specific characteristics of the data collection periods.

After acquiring the images, orthomosaics were prepared for each plot and period of evaluation. The orthomosaics were clipped and consolidated into shapefiles by applying masks, to extract the exclusive areas of each treatment within each field.

Aerial images obtained on the same day of herbicide application (NOV) and monthly for 2 months (DEC and JAN) after application were processed in the ArcGIS software package, version 10.3, using the Raster Calculator tool to calculate the normalized difference vegetation index (NDVI), which is given by the equation

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

Where (NIR) is the reflectance in the near infrared spectral range and (RED) the reflectance in the red spectral range. Subsequently, the maps of the vegetative vigor were used to identify the sprouts.

After calculating the vegetation index, the images were submitted to a supervised classification for identifying green areas (healthy areas of plants) and determining the percentage of these areas in relation to those where NDVI values indicated low vegetative vigor or presence of exposed soil. This classification was made considering only the sprouts in the rows in the pre-application period.

The supervised classification was made from artificial neural networks, in which green tones were established in the sprouts of each plot for each treatment, not including weeds and areas between the rows. This analysis allowed quantifying the percent reduction of sprout green matter for each treatment during the study period, converting the visual perception of maps into numerical information. The percentage data were submitted to analysis of variance and, when test F ($p \leq 0.05$) was significant, Tukey test was applied at 5%.

Results and discussion

The thematic maps with NDVI values for all three treatments in each plot over time (NOV, DEC, and JAN) are shown in Figure 1, 2, 3, 4 and 5.

In plot 35, the T01 maps (Figure 1) show very vigorous sprouts (NDVI values close to 1) in November, which was already expected, since herbicide was applied on the day the image was acquired. In the following month, the lower right quadrant shows some control of the sprouts, whereas the green area reduction observed in the other regions indicates only a chemical stress to the plants. Baghestani et al. (2007) pointed out that herbicides can reduce plant biomass by up to 90% in some cases, without effectively killing them.

Sixty days after application (T01_JAN), the same quadrant where partial sprout control was evident in the previous month, presented a high rate of regrowth. This result indicates that the control was not effective since the plants recovered despite the green area reduction observed 30 days after application. Similarly, Santos et al. (2007) conducted an experiment with eucalyptus, in which all plants were sprayed with 172.8 $g.ha^{-1}$

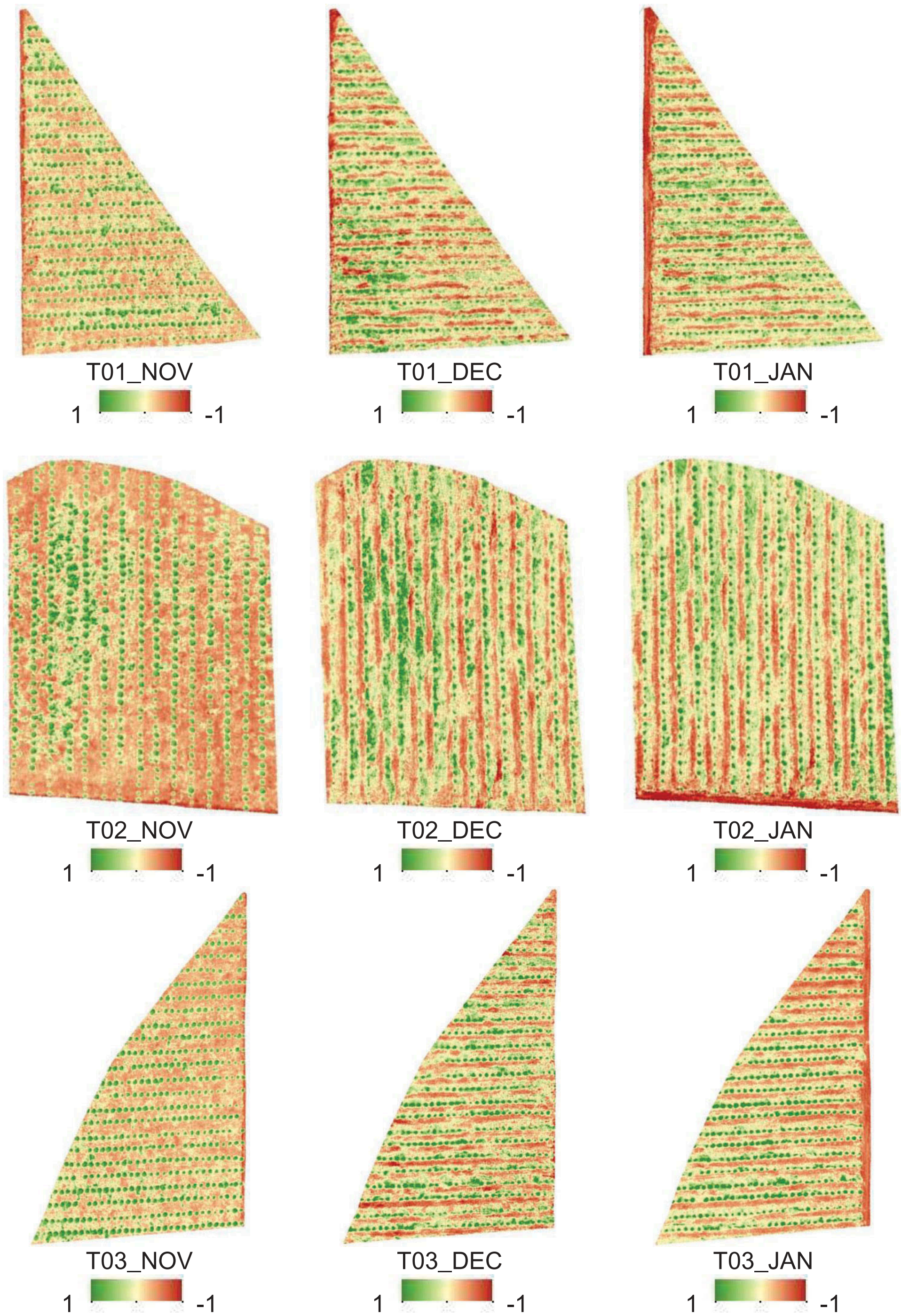

Figure 1. NDVI maps for treatments 01, 02 and 03 for plot 35 in different periods.

glyphosate, but presented emission of new (much healthier) sprouts 45 days after application.

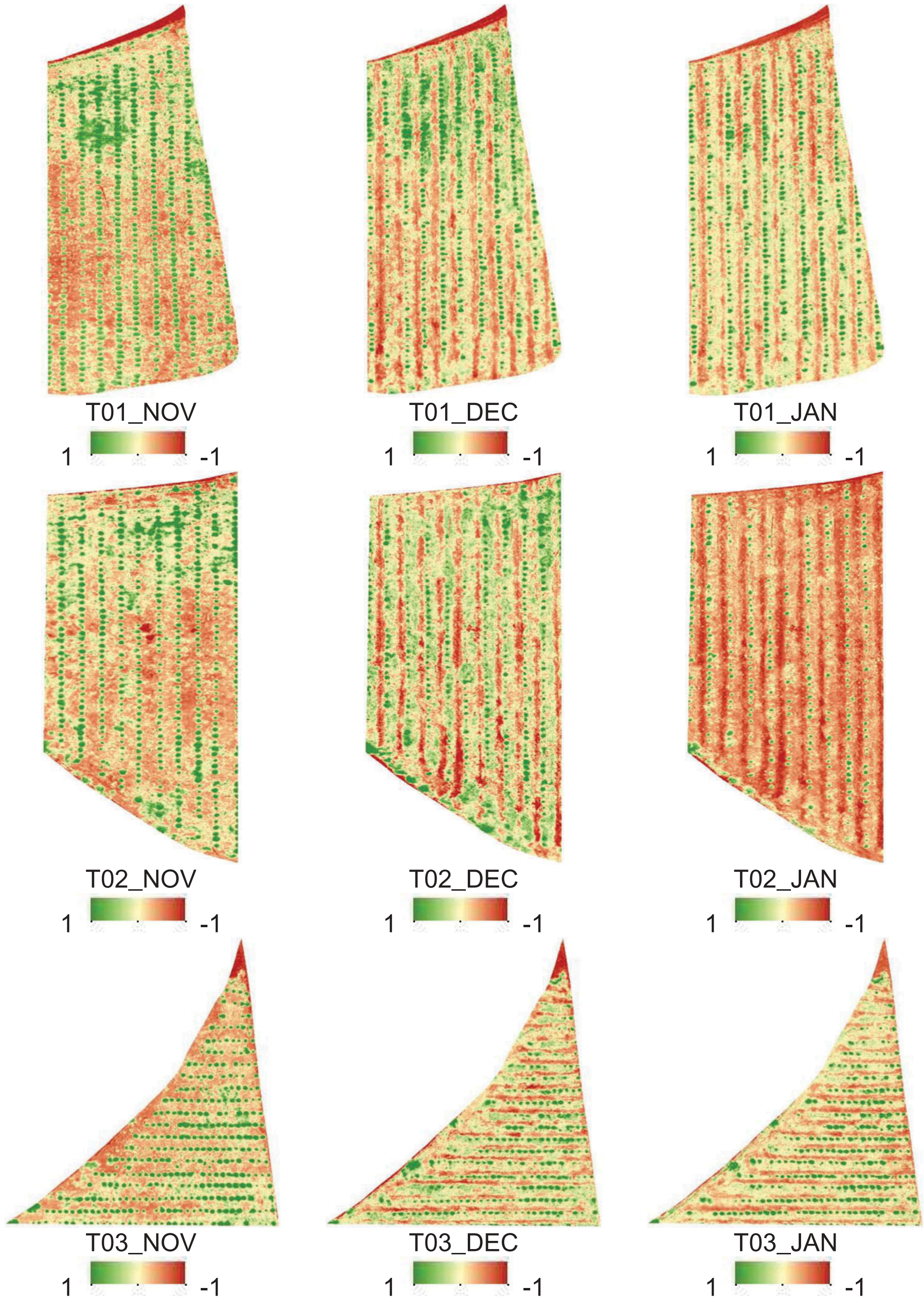

Figure 2. NDVI maps for treatments 01, 02 and 03 for plot 40 in different periods.

The T02_NOV map shows that, although vigorous, the green mass varied significantly throughout the plot, with emphasis on the sprouts of the left quadrant, which presented greater mass upon visual inspection. The T02_DEC and T02_JAN maps show that nearly the whole area is infested with weeds allied to the low control of sprouts. This is partially

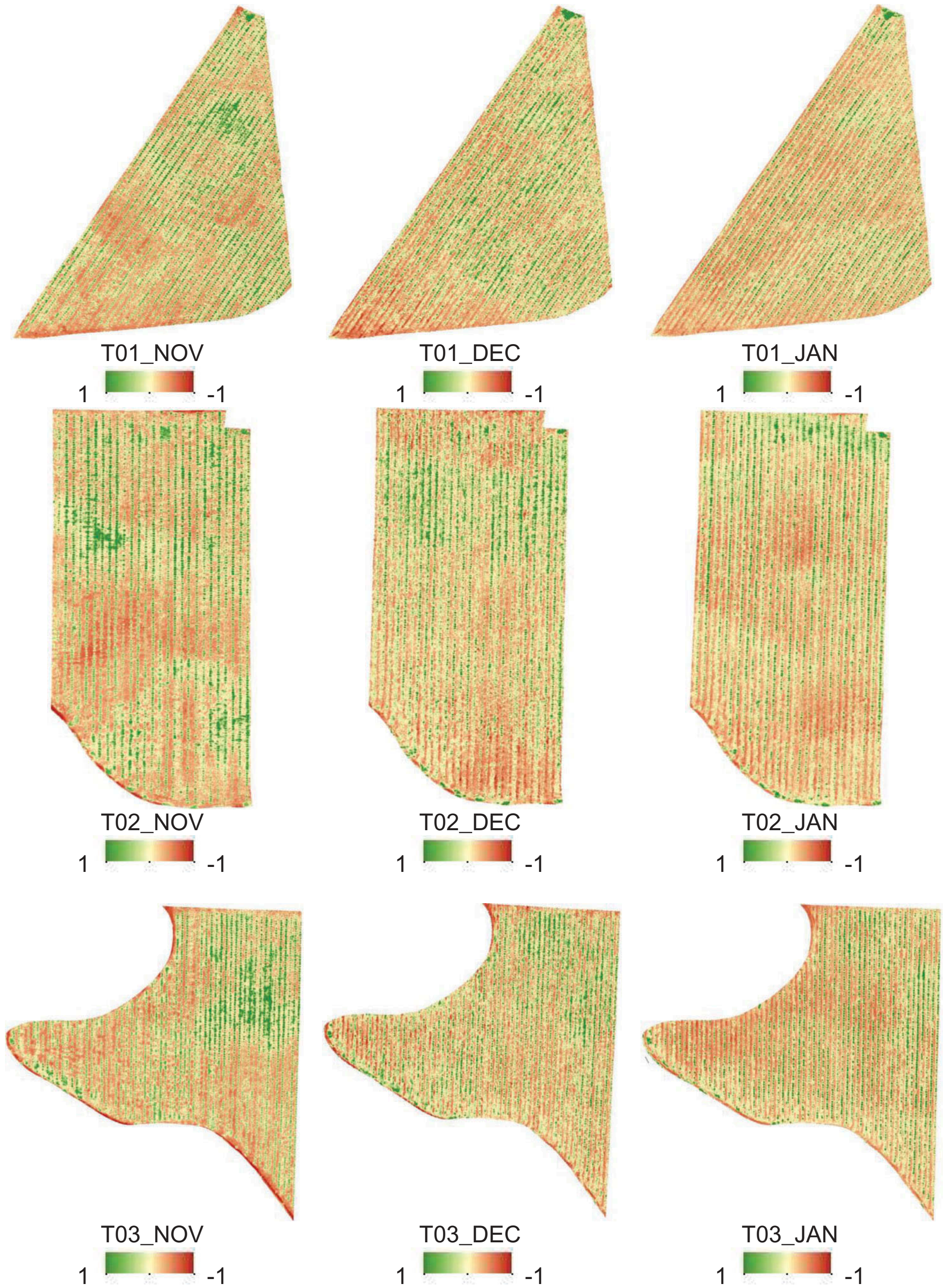

Figure 3. NDVI maps for treatments 01, 02 and 03 for plot 41 in different periods.

explained by the fact that post-emergent products were applied to each treatment in November allowing the seeds to germinate during a short period after application.

T03 behaved similarly to T01 showing low control effectiveness over the evaluated period. Despite the temporal behavior similar to T01, T03 showed no evidence of

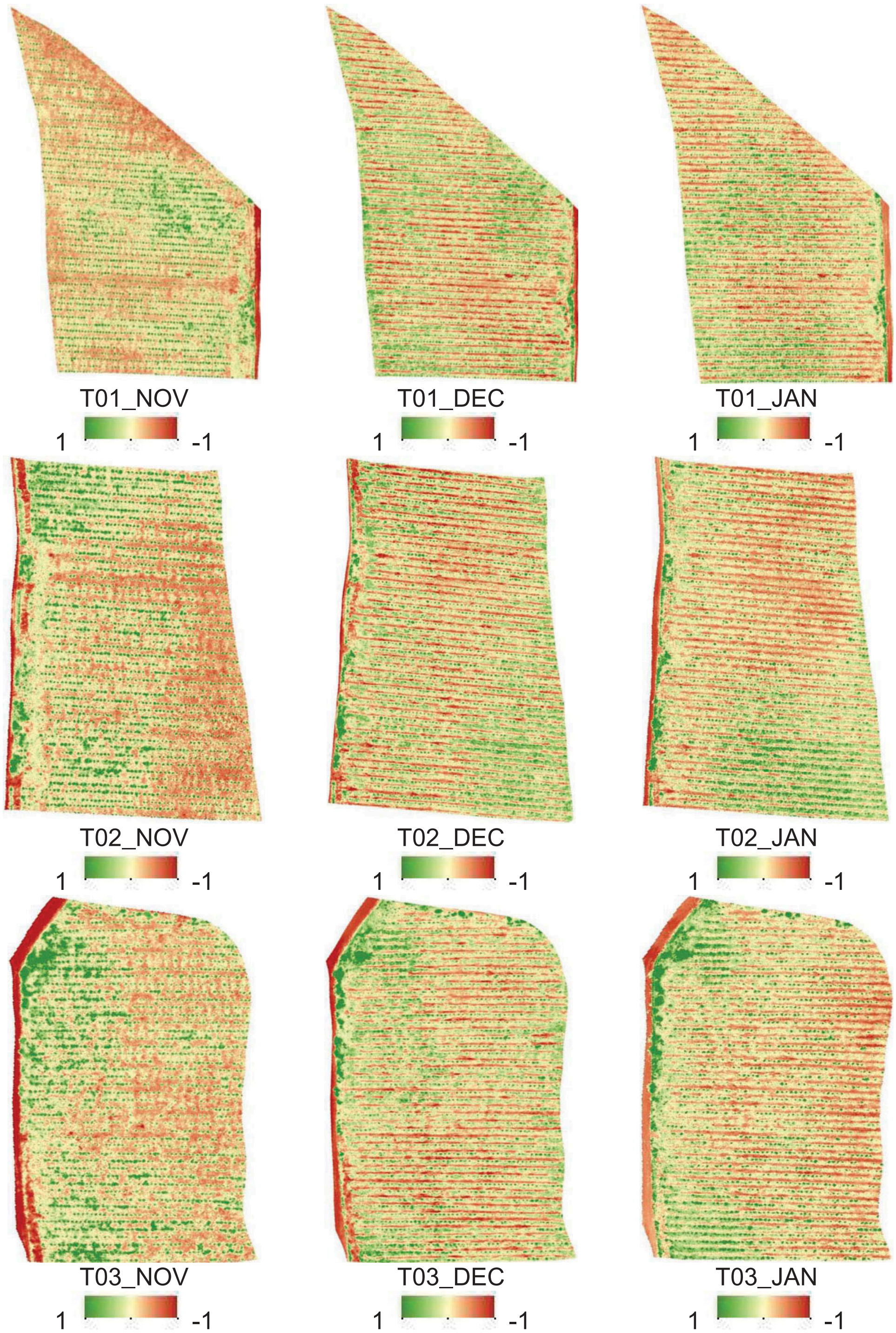

Figure 4. NDVI maps for treatments 01, 02 and 03 for plot 44 in different periods.

satisfactory control in November (pre-application). In some eucalyptus plantations, sprays can often produce the desired effect at times, but not efficiently, thus raising the question

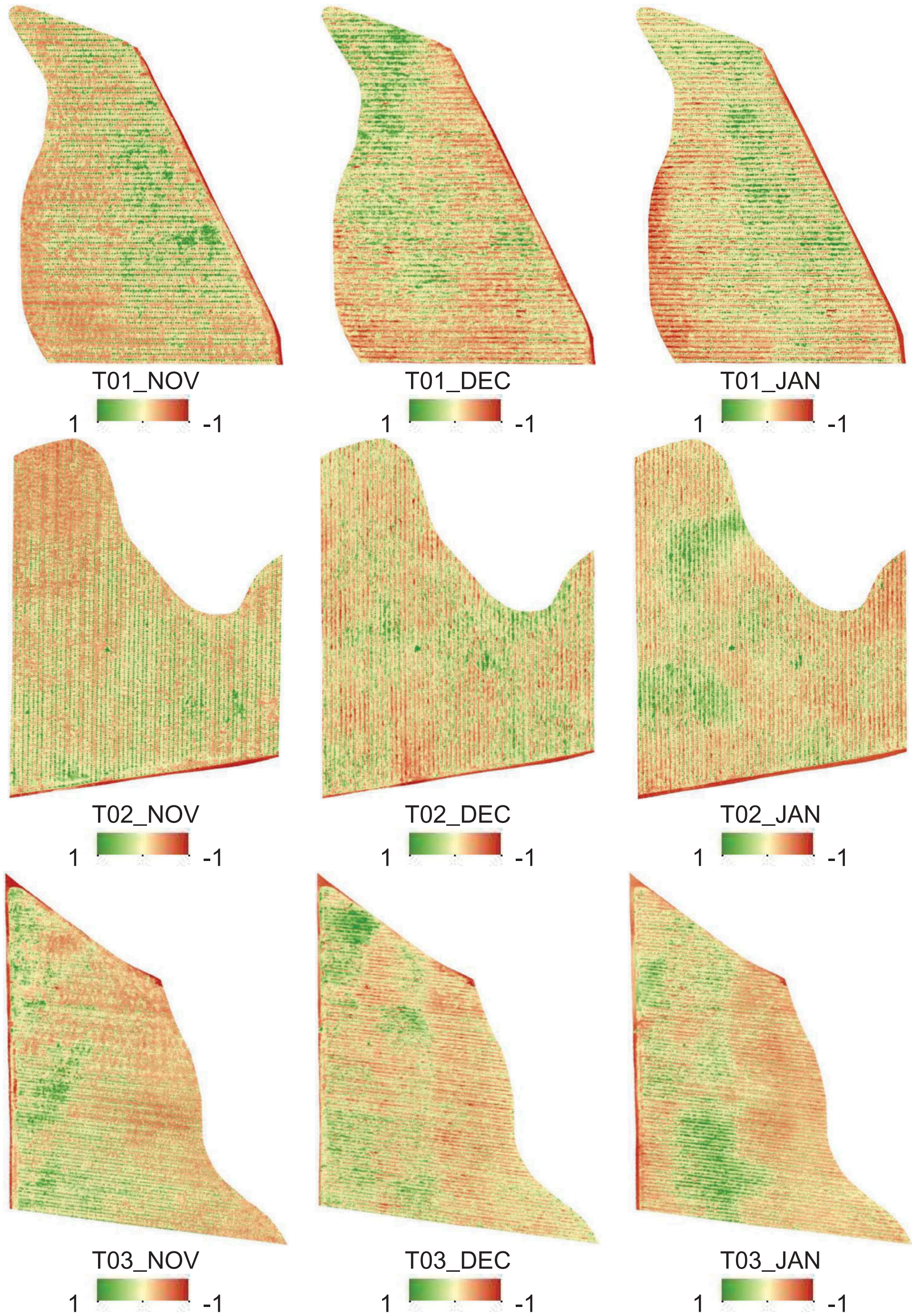

Figure 5. NDVI maps for treatments 01, 02 and 03 for plot 43 in different periods.

whether the best available technology was used, depending on the susceptibility of the clones or climatic factors (Cunha, Teixeira, Vieira, Fernandes, & Coury, 2004).

In plot 40, the T01 maps (Figure 2) show a reduction of sprouts in very specific regions of the area, especially in the lower third of the area in December compared to November. However, in January, despite the visual biomass reduction, plant regrowth with homogeneous distribution along the plot is observed. The effect of glyphosate on the eucalyptus plant, applied post-emergence, results in unstable control of the plants due, especially, to the lack of residual effect on the soil. The main reason for this lack of residual effect on the soil is that glyphosate is strongly adsorbed by colloidal particles, implying in numerous repeated applications (Rodrigues & Almeida, 2005). According to Silva, Ferreira, and Ferreira (2007), the duration of glyphosate uptake by the plant varies according to herbicide concentration, plant age, environmental conditions, and application method, among others.

In general, the T02_DEC map evidenced a satisfactory control of the sprouts in the upper third of the area compared to T02_NOV. In other regions, sprout control was observed in some spots, with sparse sprout eradication in the same period. In January, the plants are still visible in the field for the same treatment, evidencing no effective control of the sprouts similar to T01. Araújo, Silva, Thomas, and Rocha (2008) evaluated the efficiency of a post-emergent systemic herbicide associated with a leaf fertilizer and did not observe increasing control efficiency of wide leaves.

Compared to T03_NOV, the T03_DEC and T03_JAN maps showed an efficient control of sprouts only in the upper third of the area, near the border. However, over time, between 30 and 60 days post-application, the systemic herbicide and leaf fertilizer mixture applied in the sprouts was not effective. Yamashita, Betoni, Guimarães, and Espinosa (2009) indicated that has become customary to mix two or more active ingredients to increase plant control effectiveness in replanting areas. Currently, simultaneous applications of at least two herbicides have been frequently used in areas cultivated with grains to manage undesirable plants during the off-season (Gazziero, 2015).

Another alternative is to mix diluted nitrogen fertilizers in the spraying liquor to increase the efficiency of the main products (Nurse, Hamill, Kells, & Sikkema, 2008). Carvalho, Tarozzo Filho, Dias, Nicolai, and Christoffoleti (2011) investigated spraying the glyphosate active ingredient with nitrogen fertilizer solution to control viola weed in several crops and reported that the action of ammonium sulfate and urea + ammonium sulfate added to the herbicide improved the efficacy of weed control.

In plot 41 (Figure 3), in December, treatment T01 controlled sprouts efficiently in the lower left quadrant and part of the upper quadrant. It is noteworthy that the plants were not so vigorous in November, implying that glyphosate was more effective to control smaller sprouts (less biomass). It can also be visualized once again the occurrence of weeds that are well distributed throughout the area in December. T01_JAN showed low efficiency to control the sprouts in the area; the sprouts remained steady changing very little during the period from 30 to 60 days after application.

The T02_DEC map indicates a performance very similar to the T01_JAN in the superior quadrant, differing only regarding the vigor of part of the sprouts. In the lower quadrant, it was possible to verify that the control was efficient, in practically all the referred extension. However, in January, some sprouts that had been controlled showed regrowth while others with low vigor were eradicated, evidencing high temporal variability for this treatment. Generally, 30 days after application, treatments T03 and T02 had a similar result, showing a great reduction of sprout size, indicating the possibility of a more efficient control. However, this possibility was not confirmed since the T03_JAN map shows a high rate of regrowth, especially in the lower third of the area.

The T01_DEC map of plot 44 (Figure 4) indicates a generalized control of the sprouts in relation to the previous month, justifying the use of a systemic herbicide in the pre-planting period. The non-selective systemic herbicide acts against undesirable plants with greater mobility and efficient distribution of the active phytotoxic substance (Minguela & Cunha, 2010). However, in January, this same plot and treatment showed that the great majority of the controlled plants were beginning the process of issuing new sprouts.

The T02_DEC map shows no evidence of sprout control but a noticeable decrease of sprout size is observed. These physiological changes result from using glyphosate alone or in a mixture in eucalyptus plantations since its use may lead to biochemical disturbances that cause an imbalance between organic and inorganic compounds (Santos et al., 2007).

T02_JAN indicates an efficient sprout control only in the central quadrant of the area, implying that this treatment performed better 60 days after application. The T03 maps presented results similar to T02, differing only in January, when sprouts remained the same as in the previous month, without eradication.

In treatment T01, the sprouts behaved similarly over time in plots 43 (Figure 5) and 44 (Figure 4). The T02_DEC map of plot 43 shows a performance similar to T02_DEC of plot 35 (Figure 1), differentiating only in the lower quadrant of the map. In addition, 60 days after application, the behavior was similar to that already discussed for the other plots and treatments, evidencing sprout regrowth and increasing vigor.

In general, a satisfactory control of eucalyptus sprouts was not evidenced for any treatment and plot, throughout the evaluation period. In all evaluated situations, there was a considerable regrowth at 60 days despite the eradication of some sprouts 30 days after the treatments were applied.

Nonetheless, despite the reduced efficiency of the different treatments, the tool used to monitor the sprouts in the field allowed to identify visually the areas where partial sprout control was achieved, sprout biomass decreased without being eliminated, and, especially, the regrowth 60 days after the treatments were applied. In terms of sustainable silviculture, early decision-making on areas with higher biomass of plants can help in adopting a new application of chemicals in a more rational way, that is, this tool can alert specific points of the plot where one really has to apply, not on the entire plot as it usually does, causing an essential reduction in the use of herbicides. These results show the potential of using UAVs to evaluate the efficiency of herbicide application in forest production areas.

UAVs have been used efficiently in several situations in agricultural and forestry systems, as indicative of forest health, forest survival rates (Ruza et al., 2017) and different vegetative classes of agricultural crops (Fuyi et al., 2012). Morgan, Gergel, and Coops (2010) stated that the UAVs have a wide use in agricultural and forestry production systems, especially due to the easy adaptation to the needs of each project, effectively meeting the needs of each job.

To evaluate numerically the sprout control of each treatment, the percentage of the green area of each sprout in each treatment was calculated based on the NDVI values. Data were submitted to analysis of variance (Table 1) and the means were compared by Tukey test at 5% (Table 2).

Table 1. Analysis of variance of treatments (01, 02 and 03), periods (November, December, and January) and their interaction.

SV	DF	SS	MS	F
Treatment (Treat)	2	302.3	151.1	3.68^{ns}
Residue A	8	328.3	41.0	0.46
Period	2	8215.2	4107.6	46.30*
Treat x Period	4	119.7	29.9	0.34^{ns}
Residue B	24	2129.0	88.7	

SV - Source of variation; DF - degree of freedom; SS - sum of squares; MS - mean square; ns – non-significant at p > 0,05 by F test; * - significant at p > 0,05 by F test.

Table 2. Test of average percentage of the green mass of eucalyptus sprouts of T01, T02 and T03 for different periods.

TREATMENT	NOV	DEC	JAN
T01 (%)	67,9a	39,0b	36,4b
T02 (%)	64,7a	35,0b	37,5b
T03 (%)	70,1a	39,6b	46,2b

Means followed by the same lowercase letter in the row do not differ by Tukey test at p > 0,05.

The analysis of variance (Table 1) tested the significance of treatments, evaluation periods and interaction between treatments and periods (Treat x Periods). F test results showed significant difference only for the evaluation periods, indicating no statistical difference between treatments and that they behaved similarly in the different evaluation periods.

This behavior had already been observed in the NDVI maps since it was not possible to show the effectiveness of the different treatments to control eucalyptus sprouts. As previously reported, herbicides applied individually or in association with other products did not effectively eradicate the sprouts in the studied replanting area, unlike the results reported in the literature for different crops. Araújo et al. (2008) evaluated the effects of different herbicides associated or not with foliar fertilizers and reported high efficiency in the control of narrow leaf plants in bean crops.

Table 1 shows that only the evaluation periods had significant calculated F value; therefore, the green mass of the sprouts was compared for the treatments over time (Table 2).

A significant reduction in the green biomass values measured by NDVI was observed for all treatments 30 days after application. The percentage reduction was 28.9, 29.7 and 30.5% for treatments T01, T02 and T03, respectively. No significant difference was evidenced in the percentage of green sprout biomass between the interval of 30 and 60 days after application. These results confirm the previously observed behavior of sprouts after application, where only partial control of the sprouts is evident and not total eradication as desired.

Although no statistical difference was observed between the 30 and 60 days after application, the values were numerically higher for the latter, confirming the data observed in the maps, such as sprout regrowth and plant vigor.

Conclusions

The UAVs used to monitor eucalyptus sprouts allowed to identify, visually, the temporal behavior of the plants after using chemical methods to eradicate sprouts.

None of the chemical control methods used were effective to eradicate the eucalyptus sprouts.

This study presented a viable alternative for evaluating the efficiency of herbicide application in a forestry area, contributing directly to the productive process of the forests.

References

Alvares, C. A., Stape, J. L., Sentelhas, P. C., Gonçalves, J. L. M., & Sparovek, G. (2013). Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, *22*, 711–728. doi:10.1127/0941-2948/2013/0507

Araújo, G. A. A., Silva, A. A., Thomas, A., & Rocha, P. R. R. (2008). Mistura de herbicidas com adubo molíbdico na cultura do feijão. *Planta Daninha*, *26*, 237–247. doi:10.1590/S0100-83582008000100025

Baghestani, M. A., Zand, E., Soufizadeh, S., Eskandari, A., Pourazar, R., Veysi, M., & Nassirzadeh, N. (2007). Efficacy evaluation of some dual purpose herbicides to control weeds in maize (Zea mays L.). *Crop Protection*, *26*, 936–942. doi:10.1016/j.cropro.2006.08.013

Carvalho, S. J. P., Tarozzo Filho, H., Dias, A. C. R., Nicolai, M., & Christoffoleti, P. J. (2011). Participação do nitrogênio na indução de injúrias foliares e na eficácia do herbicida glyphosate. *Revista Ceres*, *58*, 516–524. doi:10.1590/S0034-737X2011000400017

Cunha, J. P. A. R., Teixeira, M. M., Vieira, R. F., Fernandes, H. C., & Coury, J. R. (2004). Espectro de gotas de bicos de pulverização hidráulicos de jato plano e de jato cônico vazio. *Pesquisa Agropecuária Brasileira*, *39*, 977–985. doi:10.1590/S0100-204X2004001000005

De Carvalho, C. B., & Bajay, S. V. (2006). O setor agropecuário no estado da Bahia: Perspectivas econômicas e intensidade energética. Proceedings of the 6. Encontro de Energia no Meio Rural.

Fuyi, T., Chun, B. B., Jafri, M. Z. M., San, L. H., Abdullah, K., & Tahrin, N. (2012). Land cover/use mapping using multi-band imageries captured by Cropcam Unmanned Aerial Vehicle Autopilot (UAV) over Penang Island, Malaysia. *Proceedings SPIE*, *8540*, 85400.

Gazziero, D. L. (2015). Misturas de Agrotóxicos em Tanque nas Propriedades Agrícolas do Brasil. *Planta Daninha*, *33*, 83–92. doi:10.1590/S0100-83582015000100010

IBÁ - Indústria Brasileira De Árvores. (2017). Relatório IBÁ. Retrieved September 25, 2017, from http://iba.org/images/shared/Biblioteca/IBA_RelatorioAnual2017.pdf.

Minguela, J., & Cunha, J. P. R. (2010). *Manual de aplicação de produtos fitossanitários*. Viçosa, Brazil: Editora Aprenda Fácil.

Morgan, J. L., Gergel, S. E., & Coops, N. C. (2010). Aerial photography: A rapidly evolving tool for ecological management. *Bioscience*, *60*, 47–59. doi:10.1525/bio.2010.60.1.9

Nurse, R. E., Hamill, A. S., Kells, J. J., & Sikkema, P. H. (2008). Annual weed control may be improved when AMS is added to below-label glyphosate doses in glyphosate-tolerant maize (Zea mays L.). *Crop Protection*, *27*, 452–458. doi:10.1016/j.cropro.2007.07.015

Rodrigues, B. N., & Almeida, F. (2005). *Guia de Herbicidas*. Londrina, Brazil: Edição dos Autores.

Ruza, M. S., Corte, A. P. D., Hentz, A. M. K., Sanquetta, C. R., Silva, C. A., & Schoeninger, E. R. (2017). Inventário de Sobrevivência de povoamento de Eucalyptus com uso de Redes Neurais Artificiais em Fotografias obtidas por VANTs. *Advances in Forestry Science*, *4*, 83–88.

Santos, H. G., Jacomine, P. K. T., Anjos, L. H., Oliveira, V. A., Oliveira, J. B., Coelho, M. R., … Cunha, T. D. (2013). *Sistema Brasileiro de Classificação de Solos*. Brasília, Brazil: Embrapa Solos.

Santos, L. D. T., Machado, A. F. L., Viana, R. G., Ferreira, L. R., Ferreira, F. A., & Souza, G. V. R. (2007). Crescimento do eucalipto sob efeito da deriva de glyphosate. *Planta Daninha*, *25*, 133–137. doi:10.1590/S0100-83582007000100014

Silva, A. D., Ferreira, F. A., & Ferreira, L. R. (2007). *Herbicidas: Classificação e mecanismo de ação [Chapter of the book Topics in weed management]* (pp. 58–117). Viçosa, Brazil: Federal University of Viçosa.

Silva, C. A., Souto, M. V. S., Duarte, C. R., Bicho, C. P., & Sabadia, J. A. B. (2015). Avaliação da acurácia dos ortomosaicos e modelos digitais do terreno gerados pelo MVANT/DNPM. *Revista Brasileira De Cartografia*, *67*, 1479–1495.

Terezan, L. H., Bernardi, M., & Silva, A. I. G. (2014, November). Controle de Qualidade Florestal na Eldorado Brasil S.A. Paper published and presented in the annals of the 50th Technical-Scientific

Meeting of the Cooperative Program on Forestry and Management. Série Técnica IPEF, Piracicaba, Brazil.

Tibúrcio, R. A. S. (2014). Desenvolvimento de pulverizador visando o controle de brotações na reforma de eucalipto (Doctoral thesis). Federal University of Viçosa, Viçosa, Brazil.

Vetorrazzi, C. A., & De Ferraz, S. F. B. (2000). *Silvicultura de precisão: Uma nova perspectiva para o gerenciamento de atividades florestais. [Chapter of the book Precision Agriculture]* (pp. 65–75). Viçosa, Brazil: Federal University of Viçosa.

Yamashita, O. M., Betoni, J. R., Guimarães, S. C., & Espinosa, M. M. (2009). Influência do glyphosate e 2, 4-D sobre o desenvolvimento inicial de espécies florestais. *Scientia Forestalis*, *37*, 359–366.