XV WORLD FORESTRY CONGRESS
Building a Green, Healthy and Resilient Future with Forests
2–6 May 2022 | Coex, Seoul, Republic of Korea

Precision monitoring of leaf-cutting ant nests in sub-orbital RGB images using deep learning

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Introduction

Leaf-cutting ants are the main pests in plantation forests at South America, causing severe defoliation, leading to production losses, plant mortality and increased susceptibility to other insects. Chemical control with sulfluramid active ingredient is the most used method. In forest crops, leaf-cutting ants must be controlled to avoid economic damage, thus there is a constant search for monitoring and controlling methods. (Zanetti et al., 2014). These ants are controlled in forest plantations, mainly using bait made from an attractive substrate and mixed with an insecticide (Britto et al., 2016), but pressure to reduce its used in these areas are increasing in society and certifying agencies (Zanuncio et al., 2016).

Objective

This proposal aimed to develop an innovative method for leaf-cutting ants nest detection in sub-orbital RGB images using deep learning techniques.

Methods

This study was carried out in a 6-month-old eucalyptus stand with 91.3 hectares in the municipality of Três Lagoas, in the State of Mato Grosso do Sul, Brazil. The images of the stand were collected by a DJI Phantom 4 Advanced aircraft with an RGB camera and processed to produce an orthomosaic with a ground-level resolution of 5.2 cm/pix. The final orthomosaic was cropped in sub-images of 98 x 81 pixels. Sub-images that contained ant nests were labelled using bounding boxes. The database used in experiments consists of 2465 images containing leaf-cutting ant nests and 2465 images of ants' nest absence (background). The YOLOv5 convolutional neural network was used as deep learning detection algorithm due its results in other contexts. It contains four different architectures, called small (s), medium (m), large (l), and extra-large (xl), each one increasing its computational complexity due different number of hidden layers and convolutional kernels. The quality of its predictions was evaluated by accuracy, Kappa, sensitivity, specificity, and absolute mean error (MAE) metrics between training and validation samples.

Results and Discussion

All the YOLOv5 architectures which were tested obtained similar results in the test stage, considering accuracy, Kappa, sensitivity, and specificity indices (Table 1). Predictions of nest areas were best performed by the YOLOv5s architecture (MAPE area=0.49), followed by YOLOv5l, YOLOv5m, and YOLOv5xl, with MAPE area values of 0.69, 1.93 and 3.65, respectively (Table 1). The accuracy of these four architectures on the test base was greater than 95%, with a difference of less than 1% between the models with the highest (YOLOv5l) and lowest (YOLOv5xl) performance. Specificity variation was low (less than 1%), with values greater than 99% in all architectures, (Table 1). Sensitivity values showed discrepancies between the different YOLO architectures, with the highest value for YOLOv5l (96.03%) and lowest for YOLOv5s (Figure 1) and YOLOv5xl, both with 93.80% accuracy in the detection of leaf-cutting ant nests.

Obtained results show that YOLO is a promising approach for precision monitoring of leaf-cutting ant nests in sub-orbital RGB images and can contribute to reduce and optimize insecticide use in plantation forests, which is aligned with the UN Sustainable Development Goals (SDGs), consisting of responsible consumption and production (Goal 12), and terrestrial life (Goal 15). Monitoring leaf-cutting ant nests in forest enables preventive control, reducing damage, reinfestation, and ponctual insecticide application only in the nest's locations (Zanuncio et al., 2016).

Fig. 1. Sample with 24 images showing the detection of leaf-cutting ant (LCA) nests in eucalyptus plantations, using RGB images acquired by unmanned aerial vehicles (UAVs) with the YOLOv5s network.

Table 1. Accuracy (Ac.), Kappa, sensitivity (Sen.), specificity (Sp.), nest area (NA) and mean absolute percentage error (MAPE) area for the test of image segmentation methods and Convolutional Neural Networks (CNN) for detecting and measuring leaf-cutting ant nests in eucalyptus plantations, using RGB images acquired by sensors mounted on unmanned aerial vehicles (UAVs).

Approach	Ac. (%)	Kappa	Sen. (%)	Sp. (%)	NA (m²)	MAE area (%)
YOLOv5xl	97.62	0.95	93.80	99.60	1120.264	3.65
YOLOv5l	**98.45**	0.96	96.03	99.62	1088.221	0.69
YOLOv5m	97.89	0.95	94.53	99.60	1101.586	1.93
YOLOv5s	97.65	0.95	93.80	99.61	1085.44	**0.49**

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