Natural Resources

Dez 2022 a Fev 2023 - v.13 - n.1

ISSN: **2237-9290**

This article is also available online at:
www.sustenere.inf.br

Spatial distribution of Atta laevigata (hymenoptera: formicidae) in forest ecosystems with mahogany in the Eastern Amazon

Atta laevigata (Hymenoptera: Formicidae) is a leaf-cutter ant that heavily defoliates mahogany plantations (Swietenia macrophylla – Meliaceae). In this work, the spatial distribution of A. laevigata was confirmed in 1 ha plots of three forest ecosystems with 13-year-old mahogany in the Eastern Amazon, Brazil. The treatments were defined as Consortium (mahogany plantation with other Meliaceae species), Monoculture (mahogany plantation only) and Enrichment (secondary forest enriched with mahogany). The sampling effort involved 80 pitfall traps buried for 48 h for treatment during eight rainy (January to June) and dry (July to December) periods over two years (2015 and 2016). All traps were georeferenced and analyzes were carried out using the SUFER 11.0 statistical software, which produced the kriging maps. Atta laevigata presented a clustered spatial distribution in all treatments with spatial dependence described by spherical and exponential models. The clusters were more concentrated at the edges of the plots than in the center, and open areas showed greater variation over time. Among the treatments, Monoculture had the smallest reach (13.7 m), with a minimum area of influence of A. laevigata of 589.65 m², while Consortium and Enrichment were considered equal minimums, with an area of influence of A. laevigata of 804.25 m².

Palavras-chave: Leaf-cutting ants; Swietenia macrophylla; Geostatistics; Forest management.

Distribuição espacial de Atta laevigata (hymenoptera: formicidae) em ecossistemas florestais com mogno na Amazônia Oriental

Atta laevigata (Hymenoptera: Formicidae) é uma formiga cortadeira que desfolha fortemente as plantações de mogno (Swietenia macrophylla – Meliaceae). Neste trabalho, foi analisada a distribuição espacial de A. laevigata em parcelas de 1 ha de três ecossistemas florestais com mogno com 13 anos de idade na Amazônia oriental, Brasil. Os tratamentos foram definidos como Consórcio (plantação de mogno com outras espécies de Meliaceae), Monocultura (somente plantação de mogno) e Enriquecimento (floresta secundária enriquecida com mogno). O esforço amostral contou com 80 armadilhas de queda enterradas por 48 horas por tratamento durante oito períodos da estação chuvosa (janeiro-junho) e seca (julho-dezembro) ao longo de dois anos (2015 e 2016). Cada armadilha foi georreferenciada e as análises foram realizadas através do software estatístico SUFER 11.0, que produziu os mapas de krigagem. Atta laevigata apresentou distribuição espacial agrupada em todos os tratamentos com dependência espacial descrita por modelos esféricos e exponenciais. Os clusters estavam mais concentrados nas bordas das parcelas do que no centro, e nas áreas abertas apresentaram maior variação ao longo do tempo. Entre os tratamentos, o Monocultivo apresentou alcance mínimo (13,7 m), com área de influência mínima de A. laevigata de 589,65 m², enquanto Consórcio e Enriquecimento apresentaram mínimos iguais, com área de influência de A. laevigata de 804,25 m².

Keywords: Formigas cortadeiras; Swietenia macrophylla; Geoestatística; Gestão florestal.

Topic: **Ciências Florestais**

Reviewed anonymously in the process of blind peer.

Received: **10/12/2022**
Approved: **12/03/2023**

Gustavo Schwartz
Wageningen University, Países Baixos (Holanda)
http://lattes.cnpq.br/0774787368316223
https://orcid.org/0000-0002-1717-4491
gustavo.schwartz@embrapa.br

Ruy Guilherme Correia
Universidade Federal Rural da Amazônia, Brasil
http://lattes.cnpq.br/0365390570808989
https://orcid.org/0000-0001-7039-8358
cciigg25@yahoo.com.br

Arthur Vinícius Ferreira dos Santos
Universidade Federal do Pará, Brasil
http://lattes.cnpq.br/7136004873949490
https://orcid.org/0000-0001-5143-240X
arturvfs@gmail.com

Raphael Lobato Prado Neves
Universidade Federal Rural da Amazônia, Brasil
http://lattes.cnpq.br/0686158492996814
https://orcid.org/0000-0002-0997-4851
raphael.lobato@outlook.com

Alexandre Mehl Lunz
Universidade Federal Rural do Rio de Janeiro, Brasil
http://lattes.cnpq.br/5160787212380163
alexandre.mehl@embrapa.br

Telma Fátima Vieira Batista
Universidade Federal Rural da Amazônia, Brasil
http://lattes.cnpq.br/8251281115341075
https://orcid.org/0000-0001-6638-4578
telmabatistacoelho@yahoo.com.br

DOI: 10.6008/CBPC2237-9290.2023.013.0001

Referencing this:
SCHWARTZ, G.; CORREIA, R. G.; SANTOS, A. V. F.; NEVES, R.L.P.; LUNZ, A. M.; MONTEIRO, O. M.; BATISTA, T. F. V.. Distribuição espacial de Atta laevigata (Hymenoptera: formicidae) em ecossistemas florestais com mogno na Amazônia Oriental. **Natural Resources**, v.13, n.1, p.1-12, 2023. DOI: http://doi.org/10.6008/CBPC2237-9290.2023.013.0001

INTRODUCTION

Atta laevigata Fr. Smith, 1858 (hymenoptera: formicidae) is a leaf-cutting ant that causes important damage in mahogany (Swietenia macrophylla King.; Meliaceae) plantations through defoliation. Mahogany is an economically important tree species with timber prices ranging from US$ 200 to eight hundred per cubic meter (SEFA, 2015). Its wood is indicated in the manufacture of luxury furniture, wainscoting, panels, decorative cut sheets and special plywood; in civil construction such as frames, cords, trimmings, shutters, blinds, baseboards, and floors. It is also used in the interior decoration of ships, sculptures, office supplies and carving pieces (SANTINI JUNIOR et al., 2021).

Mahogany presents rapid growth, easy environmental adaptability, and good trunk shape (GROGAN et al., 2002) (OLIVEIRA et al., 2020). Individuals of mahogany are easily established in different planting arrangements such as homogeneous plantings, mixed plantings, and enrichment lines in different ecosystems such as primary forests, secondary forests, agroforestry systems, or in canopy gaps opened by human activities (CARVALHO, 2007). However, mahogany is in the status of endangered (CITES, 2019), hence De Oliveira et al. (2020), affirm that it is important to implement strategies for *ex situ* and *in situ* genetic conservation such as seed collection from selected seed trees and silvicultural treatments such as the enrichment planting and seedling tending in logging gaps (GOMES et al., 2019) (NEVES et al., 2019) (SCHWARTZ et al., 2017) (VIEIRA et al., 2018).

Interactions between ants and plants are important to understand evolutionary processes of mutualistic associations (FARIAS et al., 2018). Ants are elements of many ecological interactions and have a critical role on plant species survivorship, including the germination behind trees when ants forage fruits, clean seeds, and disperse these seeds in anthills (OLIVEIRA et al., 1995) (PASSOS et al., 2003). Building nests and foraging are ant activities that influence the soil formation and the soil-plant relations. In this process, soil horizons are mixed, aerated, and enriched with nutrients (DIEHL-FLEIG, 1995). Many plant and animal species are protected by interactions with other organisms (SCHOWALTER, 2006), such leaf-cutting ants of the genera Atta and Acromyrmex, which cultivate fungi to feed their colonies (CURRIE, 2001). Leaf-cutting ants are considered important forest pests in different forest growth stages, since they cause considerable losses due to intensive and constant attacks (SANTOS et al., 2015). They can cause damage during any plant developmental stage, including cuttings in leaves, sprouts, fine twigs, and flowers, which are transported to underground nests, serving as substrate for symbiont fungi (CATALANI et al., 2020). Leaf-cutting ants' control is an important variable considered in the productivity calculations of commercial tree plantations. Ants of the genus *Atta* consume 13-17% of the leaf biomass yearly produced by tree species in Cerrado, the Brazilian savannah (CHERRETT, 1989) (COSTA et al., 2008) (CALDATO et al., 2020).

Geostatistical methods are used for population sampling and monitoring of leaf-cutting ants in planted forests (LASMAR et al., 2012) (SOARES et al., 2020), as they permit to identify in detail the most infested points of a given forest plot and control them more precisely (DELLA, 2011). Such methods have been successfully applied in eucalyptus plantations in the Atlantic Forest, Brazil (MENDONÇA, 2008). In the

Brazilian Amazon, geostatistical methods have been employed to evaluate spatial patterns of other economically relevant pests, as reported for *Metamasius hemipterus* (Coleoptera: Curculionidae), *Opsiphanes invirae* (Lepidoptera: Nymphalidae), and *Rhynchophorus palmarum* (Coleoptera: Curculionidae) in palm oil plantations (DIONISIO et al., 2015) (PINHO et al., 2016) (BRANDÃO et al., 2017).

In this context, the objective of this work was to compare the spatial distribution of the leaf-cutting ant *A. laevigata* in forest ecosystems with mahogany through the use of geostatistical methods.

METHODOLOGY

Fieldwork was carried out in a commercial area for reforestation with mahogany in the eastern Amazon, municipality of Aurora do Pará, state of Pará, Brazil (2º10’00” S and 47º32’00” W; 50 m a.s.l.). The area belongs to the Brazilian company Tramontina S.A. Eight samplings were done: four collections in 2015 (two in the rainy and two in the dry season) and other four collections in 2016 (again, two collections per season).

According to the Köppen classification, the region’s climate is Aw, tropical humid, with annual average temperature of 25 °C, relative humidity of 85%, annual precipitation of 2,350 mm, and a dry season from July to December (IBGE, 2016). Soils are mainly Yellow Latosols with medium to clayey textures and lateritic concrete, quartz sand, and associated hydromorphic with alluvial soils near the Capim river (IBGE, 2016).

Three 1-ha plots representing three 13-year-old forest ecosystems with mahogany far at least 1,000 m each other were established. The three treatments, named Consortium, Monoculture, and Enrichment, are described below:

a) Consortium: Mahogany planting (planting spacing of 3 m x 3 m = 1,111 trees/ha) associated with other Meliaceae species such as Australian cedar (Toona ciliata) (planting spacing of 4 m x 4 m = 625 trees/ha), African mahogany (Khaya grandifoliola) (planting spacing of 4 m x 4 m = 625 trees/ha), and neem (Azadirachta indica) (planting spacing of 5 m x 5 m = 400 trees/ha). Location: 02º16’07” S; 47º58’04” W.

b) Monoculture: Mahogany planting, only (planting spacing of 3 m x 3 m = 1,111 tree/ha). Location: 02º17’09” S; 47º57’06” W.

c) Enrichment: 7-year-old secondary forest enriched with mahogany (planting spacing of 3 m x 3 m = 400 trees/ha). By the time of data collection, the enrichment planting was 13 years old while the secondary forest was 20 years old. The ten most common tree species in the sampled forest were: Casearia arborea (Salicaceae), Tapirira guianensis (Anacardiaceae), Abarema cochleata (Fabaceae), Lecythis lurida (Lecythidaceae), Sapindus saponaria (Sapindaceae), Myrcia deflexa (Myrtaceae), Vismia guianensis (Hypericaceae), Connarus perrottetii (Connaraceae), Mabea angustifolia (Euphorbiaceae), and Cordia exaltata (Boraginaceae). Location: 02º16’12” S; 47º59’01” W.

Leaf-cutting ants were sampled through pitfall traps in 500-ml plastic recipients. Each trap was buried in the soil and filled with 300 ml of alcohol-70% and added by few drops of detergent. Traps remained in the field for 48 h. The sampling method followed the Ants of the Leaf Litter protocol, where twenty traps per hectare are sufficient to sample 70% of the ant species associated with soil in each area (AGOSTI et al., 2000). Each 1-ha plot was divided in four 50 x 50 m (2,500 m2) sub-plots to attain better spatial distribution of traps inside the sampling area. Eighty traps per treatment (20 per sub-plot) were established with distances not shorter than 10 m among them. Every trap was considered as a sampling unit, with eighty units per treatment with 240 traps in total. The collected ants were identified at the species level, using a stereoscopic microscope with a 40-fold magnification as well as dichotomous keys (TRIPLEHORN et al., 2011) (RAFAEL et al., 2012).

To analyze the spatial distribution of Atta laevigata in the forest ecosystems, a geostatistical method was used where the semivariogram modeling came as the first step (SILVA et al., 2011). Every trap was geo-referenced, and the values were analyzed with the statistical software SUFER 11.0 (GOLDEN SOFTWARE, 2012). Maps of A. laevigata occurrence and spatial distribution were built using the kriging interpolation method (VIEIRA et al., 1983).

The semivariograms that show the kind and shape of the spatial dependence were adjusted through the construction of a semivariance model, described by the equation:

$$Y^*(h)=\frac{1}{2N(h)}\sum_{i=1}^{N(h)}[Z(Xi)-(Xi+h)]^2$$

where, γ (h) is the semivariance;

N (h) number of insect pair observations [Z (i); Z(xi+h)] separated by the distance h.

After that, data were adjusted to the spherical, exponential, Gaussian, and power semivariogram models. In this study, the spherical adjusted semivariogram model was described according to the following equations:

$$y(h)=C_0+C_1\left[\frac{3}{2}\left(\frac{h}{a}\right)-\frac{1}{2}\left(\frac{h}{a}\right)^3\right], \qquad 0 < h < a$$

$$y(h)=C_0+C_1, \qquad h \geq a$$

The parameters referring to the semivariogram were threshold (C0 + C1), the nugget effect (C0), and the reach (a). Threshold consists in the semivariogram value corresponding to its range, that is, from a given point onwards there is no more spatial dependence between samples. The nugget effect is the semi-variance at close points, when the distances between the sample units are very small, and range measures the limit distance of spatial dependence. Thus, the kriging maps were built using the spatial dependence modeled in the semivariogram and estimated values in any position of the field without trends and with minimal variance. This permits to follow the variable behavior in the study through contour lines, scale bars, and surface maps. To classify spatial dependence, the method described by Cambardella et al. (1994) was applied. The method considers strong spatial dependence of the semivariogram with the nugget effect less than 25% of the threshold, moderate dependence between 25% and 75%, and weak dependence with value greater than 75%.

RESULTS

A total of 80,154 individuals of *Atta laevigata* were identified in the different ecosystems. Among the three areas evaluated, 25,855 individuals were collected in the consortium ecosystem, 27,688 in the monoculture, and 26,611 in the enriched secondary forest. Highest densities of individuals increased in the second year, in both assessed periods, where the monoculture in the dry season (October) reached the largest number of insects (Figure 1).

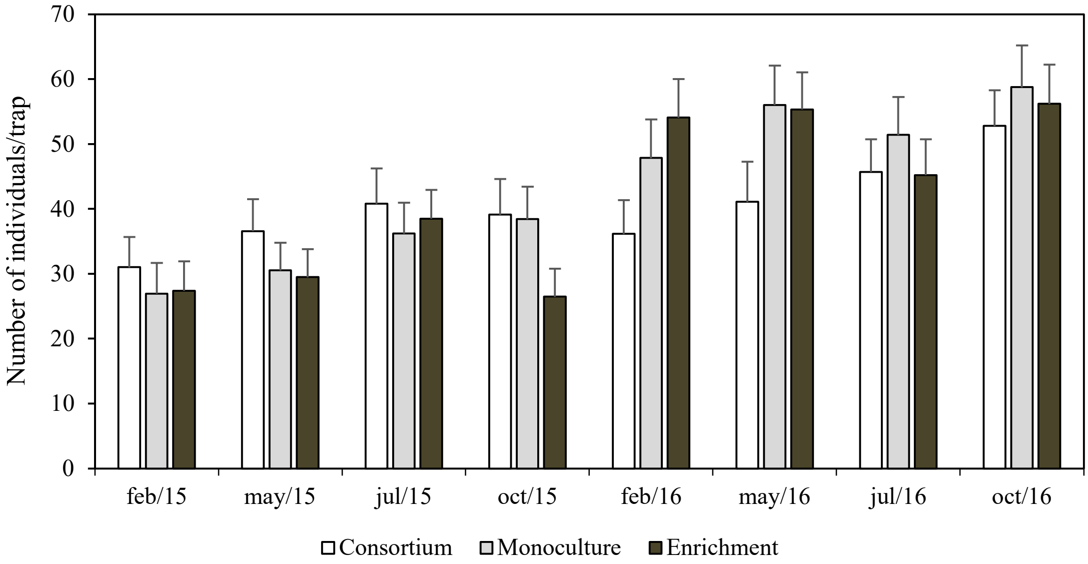

Figure 1: Population variation of the leaf-cutting ant *Atta laevigata* sampled through pitfall traps in three forest ecosystems (consortium, monoculture, and enrichment) with mahogany (*Swietenia macrophylla*) in eastern Amazon, Brazil.

In the treatments Consortium and Enrichment, the best fitted model to the population of *A. laevigata* was the spherical, indicating a clustered spatial distribution (Figure 2 and Figure 4). The spherical model was also the best fit model in most of the analyzed periods of the treatment Monoculture, followed by the exponential model (Figure 3).

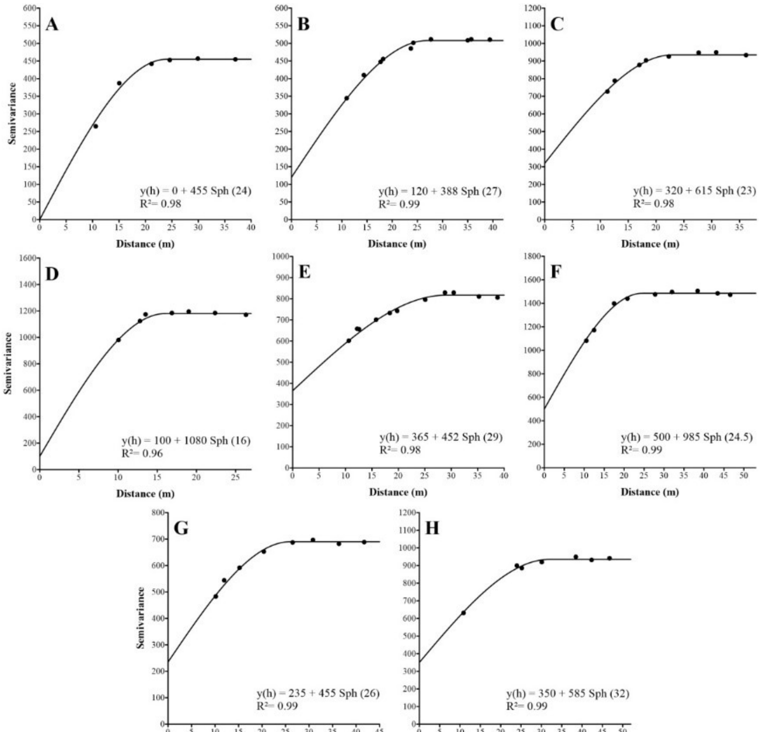

Figure 2: Adjusted semivariograms to the space models of the leaf-cutting ant *Atta laevigata* spatial distribution in the treatment Consortium of a forest ecosystem with mahogany (*Swietenia macrophylla*) during the periods of Feb/15 (A), May/15 (B), Jul/15 (C), Oct/15 (D), Feb/16 (E), May/16 (F), Jul/16 (G), and Oct/16 (H) in the eastern Amazon, Brazil.

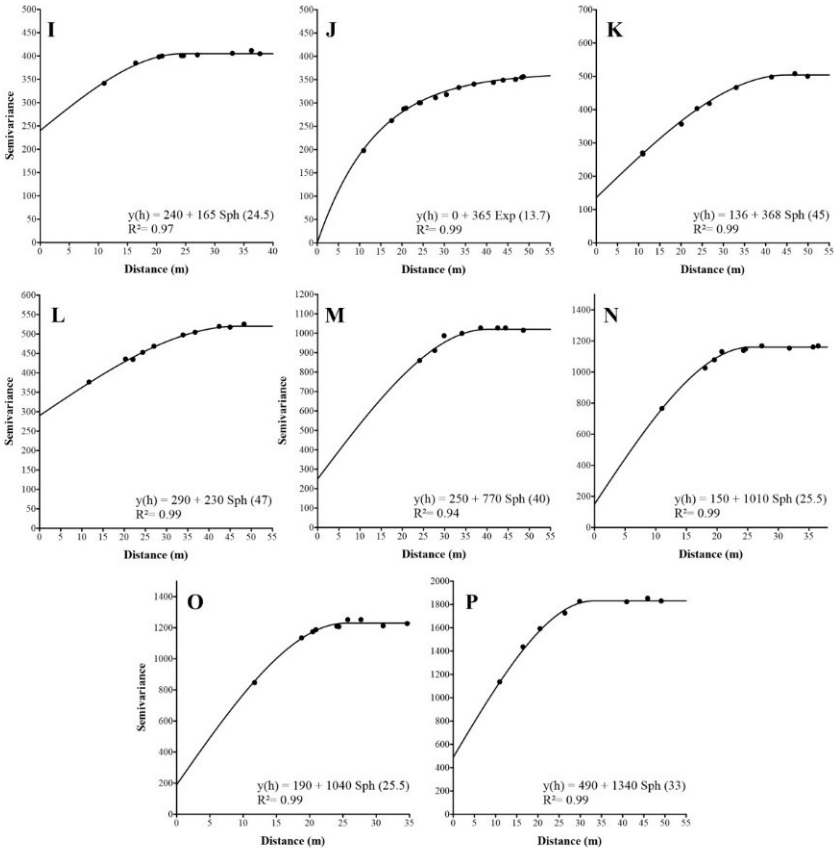

Figure 3: Adjusted semivariograms to the space models of the leaf-cutting ant *Atta laevigata* spatial distribution in the treatment Monoculture of a forest ecosystem with mahogany (*Swietenia macrophylla*) during the periods of Feb/15 (I), May/15 (J), Jul/15 (K), Oct/15 (L), Feb/16 (M), May/16 (N), Jul/16 (O), and Oct/16 (P) in the eastern Amazon, Brazil.

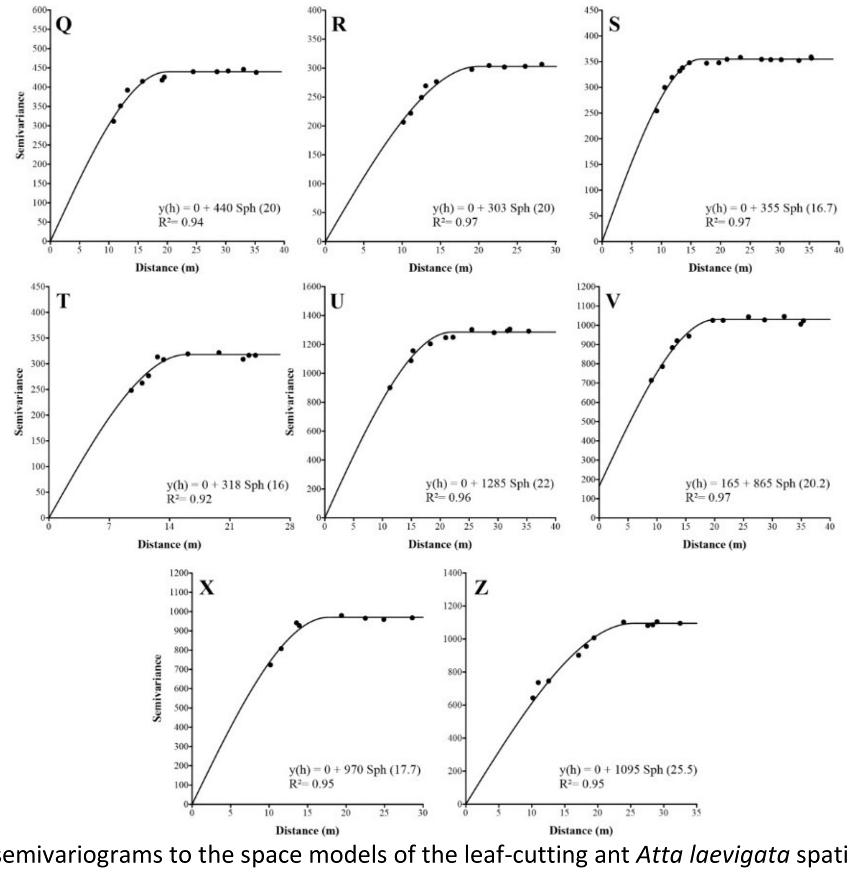

Figure 4: Adjusted semivariograms to the space models of the leaf-cutting ant *Atta laevigata* spatial distribution in the treatment Enrichment of a forest ecosystem with mahogany (*Swietenia macrophylla*) during the periods of Feb/15 (Q), May/15 (R), Jul/15 (S), Oct/15 (T), Feb/16 (U), May/16 (V), Jul/16 (X), and Oct/16 (Z) in the eastern Amazon, Brazil.

Determination coefficient (R^2) values of the adjusted models of the analyzed variables varied from 0.915 to 0.999 for the adjustments of the semivariogram models described by the spherical and exponential models. This indicates spatial dependence in the sampled population of *A. laevigata* (Table 1). From all analyzed periods and treatments tested in mathematical models adjusted, only one fitted the exponential model, all the others fitted the spherical model. The degrees of spatial dependence (DSP) (parameter k) of the semivariogram models ranged from 0.000 to 0.593, indicating spatial dependence from strong (DSP<0.25) to moderate (0.25 < DSP <0.75). Overall, the models presented low range and high values regarding the nugget effect. The difference between these two parameters explains the high values of spatial dependence. Ranges (a) of the selected models varied from 16.0 m (Oct/2015) to 32.0 m (Oct/2016) in Consortium, while in Monoculture they varied from 13.7 m (May/2015) to 47 m (Oct/2015), presenting the largest calculated ranges. Enrichment had the lowest range, varying from 16.0 m (Oct/2015) to 25.5 m (Oct/2016). The highest densities occurred in Consortium and Monoculture (Fig 5, 6, and 7), which had lower plant diversity.

Table 1: Adjusted semivariograms parameters to the spherical model, exponential model, nugget effect (C0), sill (C1), range in meters (a), determination coefficient (R^2), and degree of spatial dependence (K), for geostatistical analysis of the spatial distribution of the leaf-cutting ant *Atta laevigata* in forest ecosystems with mahogany (*Swietenia macrophylla*) in the eastern Amazon, Brazil.

Treat.	Period	Parameters			Area[a] (m^2)	Model	R^{2b}	K^c	Spatial Dependence
		C0	C1	a (m)					
Consortium	Feb/2015	0	455	24.0	1809.56	Spherical	0.980	0.000	Strong
	May/2015	120	388	27.0	2290.22	Spherical	0.988	0.236	Strong
	Jul/2015	320	615	23.0	1661.90	Spherical	0.984	0.342	Moderate
	Oct/2015	100	1080	16.0	804.25	Spherical	0.963	0.085	Strong
	Feb/2016	365	452	29.0	2642.08	Spherical	0.975	0.447	Moderate
	May/2016	500	985	24.5	1885.74	Spherical	0.989	0.337	Moderate
	Jul/2016	235	455	26.0	2123.71	Spherical	0.989	0.341	Moderate
	Oct/2016	350	585	32.0	3216.99	Spherical	0.993	0.374	Moderate
Monoculture	Feb/2015	240	165	24.5	1885.74	Spherical	0.970	0.593	Moderate
	May/2015	0	365	13.7	589.65	Exponential	0.999	0.000	Strong
	Jul/2015	136	368	45.0	6361.72	Spherical	0.999	0.270	Moderate
	Oct/2015	290	230	47.0	6939.77	Spherical	0.995	0.558	Moderate
	Feb/2016	250	770	40.0	5026.54	Spherical	0.943	0.245	Strong
	May/2016	150	1010	25.5	2042.82	Spherical	0.990	0.129	Strong
	Jul/2016	190	1040	25.5	2042.82	Spherical	0.985	0.154	Strong
	Oct/2016	490	1340	33.0	3421.19	Spherical	0.994	0.268	Moderate
Enrichment	Feb/2015	0	440	20.0	1256.64	Spherical	0.937	0.000	Strong
	May/2015	0	303	20.0	1256.64	Spherical	0.974	0.000	Strong
	Jul/2015	0	355	16.7	876.16	Spherical	0.970	0.000	Strong
	Oct/2015	0	318	16.0	804.25	Spherical	0.915	0.000	Strong
	Feb/2016	0	1285	22.0	1520.53	Spherical	0.963	0.000	Strong
	May/2016	165	865	20.2	1281.89	Spherical	0.982	0.160	Strong
	Jul/2016	0	970	17.7	984.23	Spherical	0.948	0.000	Strong
	Oct/2016	0	1095	25.5	2042.82	Spherical	0.950	0.000	Strong

a: Calculated area by the formula πr^2 **b:** Values close to “1” indicate good fit **c:** Relation of $C_0 / (C_0 + C_1)$

Most of the clusters were related to the location of the forest ecosystems evaluated. The kriging maps indicated a clustered spatial distribution of *A. laevigata*, where density variation is showed by different colors in the kriging maps. Dark green to red indicate respectively, the smallest to the largest ant densities, where quantities are represented through contour lines and scale bars (Figure 5, Figure 6, and Figure 7). When considered all periods and treatments assessed, the clusters placed in open areas tended to vary over time. The minimum range found for Monoculture was 13.7 m, with a minimum ant influence area of 589.65 m², while Consortium and Enrichment reached equal minimums, with an ant influence area of 804.25 m².

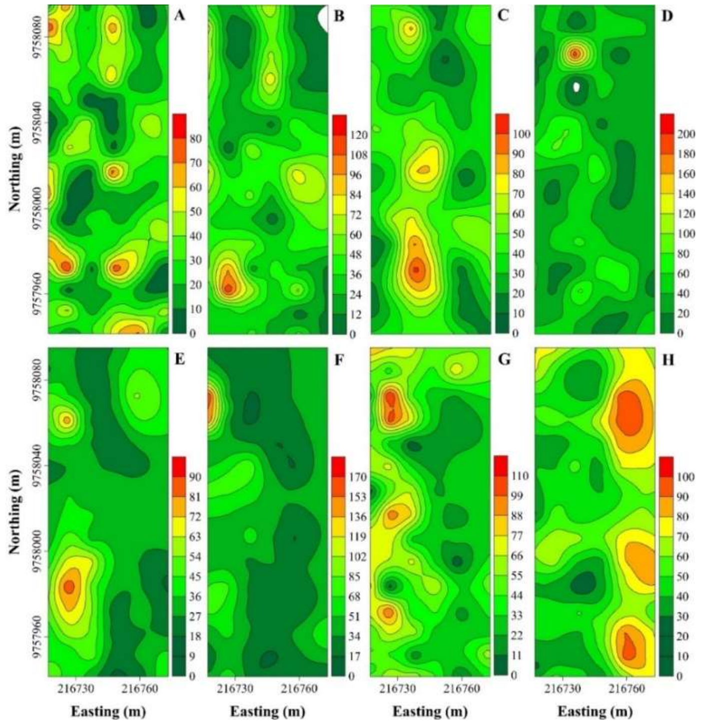

Figure 5: Kriging maps of the leaf-cutting ant *Atta laevigata* spatial distribution in the treatment Consortium of a forest ecosystem with mahogany (*Swietenia macrophylla*) during the periods of Feb/15 (A), May/15 (B), Jul/15 (C), Oct/15 (D), Feb/16 (E), May/16 (F), Jul/16 (G), and Oct/16 (H) in the eastern Amazon, Brazil.

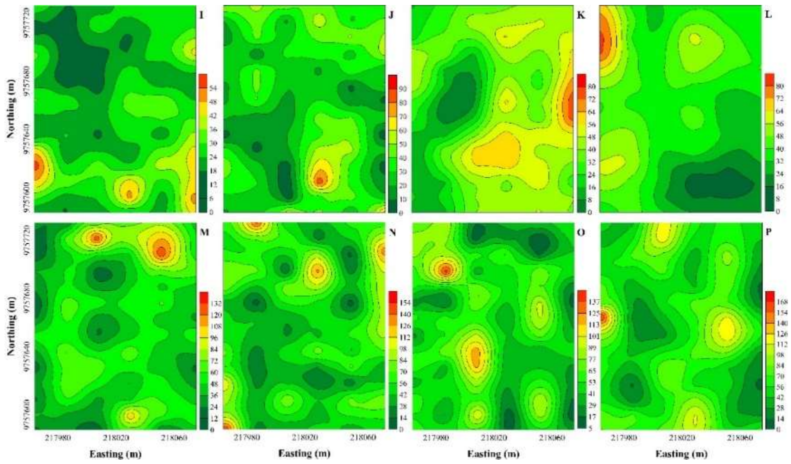

Figure 6: Kriging maps of the leaf-cutting ant *Atta laevigata* spatial distribution in the treatment Monoculture of a forest ecosystem with mahogany (*Swietenia macrophylla*) during the periods of Feb/15 (I), May/15 (J), Jul/15 (K), Oct/15 (L), Feb/16 (M), May/16 (N), Jul/16 (O), and Oct/16 (P) in the eastern Amazon, Brazil.

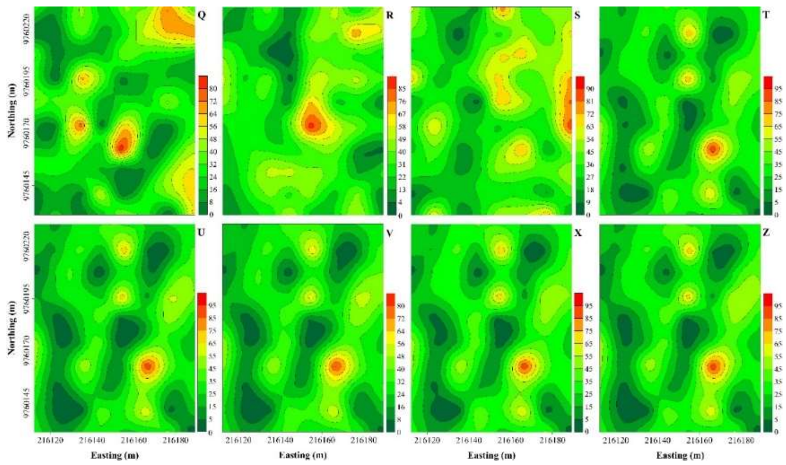

Figure 7: Kriging maps of the leaf-cutting ant *Atta laevigata* space distribution in the treatment Enrichment of a forest ecosystem with mahogany (*Swietenia macrophylla*) during the periods of Feb/15 (Q), May/15 (R), Jul/15 (S), Oct/15 (T), Feb/16 (U), May/16 (V), Jul/16 (X), and Oct/16 (Z) in the eastern Amazon, Brazil.

DISCUSSION

During the rainiest months of the first year, ant densities were higher, probably due to behavioral changes in response to direct mechanic effects caused by precipitation (FARIAS et al., 2018). Foraging ants have their activities directly affected by raindrops (SUJIMOTO et al., 2019). Leaf-cutting ants can foresee adverse weather conditions, detecting changes in the atmospheric pressure. Decreases in the atmospheric pressure are indirectly related to higher probabilities of rain and strong winds. Once detecting such pressure decreases, leaf-cutting ants respond with higher efficiency on the individual activity. On the other hand, increases in the atmospheric pressure indicate higher chances of sunlight and dry weather, which results in lower potential of the ants foraging (SUJIMOTO et al., 2019).

Nests of *A. laevigata* are built in both sunny and shaded places, surrounded by foraging trails. These trails (chemical and physical paths) have no vegetation or other obstacles, they link supply holes to the attacked plants and promote massive recruitment of worker ants to attack other plants (DELLA, 2011). Furthermore, *A. laevigata* prefers dry or withered leaves, since these leaves maintain nutrients with reduced amounts of repelling substances (VASCONCELOS et al., 1996).

Regarding the best fitted model to the population of *A. laevigata*, the spherical, indicating a clustered spatial distribution in the treatments Consortium and Enrichment, they presented the best fit in studies with insects' spatial distribution (FARIAS et al., 2004) (DINARDO-MIRANDA et al., 2010) (FARIAS et al., 2018).

Mendonça (2008) showed that the spatial dependence between leaf-cutting ant nests in eucalyptus in the Atlantic Forest reached 35 m, with a clustered spatial distribution of the nests under distances lesser than 35 m. However, in distances longer than 35 m, the spatial distribution becomes random. The spatial distribution maps presented different patterns of *A. laevigata* densities in all ecosystems, where the lowest densities occurred in Enrichment. The lowest density in Enrichment was probably due to the 20-year-old secondary forest and 13-year-old mahogany planting that presented great plant diversity and consequent more species diversity of ants and lower incidence of *A. laevigata*.

The clustered spatial distribution of anthills can be related to the micro-habitats' distribution, mutualistic interactions, environmental heterogeneity, or by ramifications of the mother colony when in the nesting stage (DIEHL-FLEIG, 1995) (CALDATO et al., 2020). Another possible cause behind nest aggregation is the edge effect, since it provides better light conditions and more palatable plants than under the forest canopy (BRESHEARS et al., 1998). In commercial eucalyptus plantations, there is a decrease in the number of *Atta* colonies from the edge to the plot center, which results in larger nests concentration in the plot edges (SOSSAI et al., 2005).

There are differences between ant nests and surrounding soil in physical, chemical, and biological parameters. Ants may affect certain soil parameters in different ways under different conditions, as increasing pH in acidic soil and decreasing pH in alkaline soil (DLUSSKIJ, 1967) (FROUZ et al., 2003).

Malozemova et al. (1973), found that *Formica polyctena* and *Formica lugubris* shift pH from acidic to neutral values more intensively than *Formica pratensis*. Measuring soil nutrient content (exchangeable P, N, K, and pH) and the tree growth in ecosystems with mature spruce trees of Norway at four distances from the nearest ant hill (0-1, 3-5, 10-50 and > 200 m). Frouz et al. (2008), founded that soil nutrients and soil pH were higher near ant nests (< 5 m) also having the second highest growth rates, in which they believe that trees may having access to a larger supply of soil nutrients near ant nests. Brazilian mahogany does not tolerate acidic soils and that it is highly dependent on calcium for increased production (DOLÁCIO et al., 2021). So, does the proximity of the *A. laevigata* ant hills influence the growth of mahogany in different ecosystems? Results of geostatistical methods allied to growth rates by distances of ant hills could mitigate why certain trees grow faster than others as described in papers of Meliaceae trees under silvicultural treatments in different ecosystems (LOPES et al., 2008) (NEVES et al., 2019) (VIEIRA et al., 2018).

CONCLUSIONS

Our results show that *Atta laevigata* presented a clustered spatial distribution, which was observed in all three treatments. The spatial distribution of t *A. laevigata* is explained by spatial dependence described by spherical and exponential models. Clusters were more concentrated in plots edges than in the center, and in open areas clusters showed more variation over time. Regarding the treatments, Monoculture presented the minimum range (13.7 m), with the minimum *A. laevigata* influence area of 589.65 m², and Consortium and Enrichment had equal minimums, with an *A. laevigata* influence area of 804.25 m².

REFERENCES

AGOSTI, D.; ALONSO, L. E.. The All protocol: a standard protocol for the collection of ground-dwelling ants. In: AGOSTI D.; MAJER, J. D.; ALONSO, L. E.; SCHULTZ, T. R.. **Ants:** Standard methods for measuring and monitoring biodiversity. Washington: Smithsonian Institution Press, 2000. p.204-206.

BRANDÃO, A. D. S.; FARIAS, P. R. S.; DIONÍSIO, L. F. S.; TINÔCO, R. S.; SILVA, A. G. S.; SILVA, T. A. F.. Spatial and temporal distribution of Opsiphanes invirae (Lepidoptera: Nymphalidae) in oil palm, Pará State, Brazil. **Revista Brasileira de Ciências Agrárias**, v.12, n.4. p.464-469, 2017. DOI: https://doi.org/10.5039/agraria.v12i4a5479

BRESHEARS, D. D.; NYHAN, J. W.; HEIL, C. E.; WILCOX, B. P.. Effects of woody plants on microclimate in a semiarid woodland: soil temperature and evaporation in canopy and intercanopy patches. **Int J Plant Sci**, v.159, p.1010-1017, 1998.

CALDATO, N.; CAMARGO, R.; SOUSA, K. K.; FORTI, L. C.; LOPES, J. F.; FOURCASSIÉ, V.. Longitudinal study of foraging networks in the grass-cutting ant atta capiguara Gonçalves, 1944. **Neotrop Entomol**, v.49, p.643-651, 2020, DOI: https://doi.org/10.1007/s13744-020-00776-9

CAMBARDELLA, C. A.; MOORMAN, T. B.; NOVAK, J. M.; PARKIN, T. B.; KARLEN, D. L.; TURCO, R. F.; KONOPKA, A. E.. Field-scale variability of soil properties in central Iowa soils. **Soil Sci Soc Am J**, v.58, p.1501-1511, 1994. DOI: https://doi.org/10.2136/sssaj1994.03615995005800050033x

CARVALHO, P. E. R.. **Mogno swietenia macrophylla**. Colombo: Circular Técnica 140, 2007.

CATALANI, G. C.; CAMARGO, R. S.; SOUSA, K. K. A.; CALDATO, N.; SILVA, A. A. C.; FORTI, L. C.. Fat-soluble substance flow during symbiotic fungus cultivation by leaf-cutter ants. **Neotrop Entomol**, v.49, p.116-123,2020. DOI: https://doi.org/10.1007/s13744-019-00718-0

CHERRETT, J. M.. The biology, pest status and control of leaf-cutting ants. In: RUSSELL, G. E.. **Biology and population dynamics of invertebrate crop pests**. Andover: Intercept, 1989. p.171-207.

CITES. **Conventional on international trade in endangered species of wild fauna and flora**. Appendix II, 2019.

COSTA, N. A.; VASCONCELOS, H. L.; VIEIRA-NETO, E. H. M.; BRUNA, E. M.. Do herbivores exert top-down effects in Neotropical savannas? Estimates of biomass consumption by leaf-cutter ants. **J Veg Sci**, v.19, p.849-854, 2008. DOI: https://doi.org/10.3170/2008-8-18461

CURRIE, C. R.. Prevalence and impact of a virulent parasite on a tripartite mutualism. **Oecologia**, v.128, p.99-106, 2001.

DELLA, L. T. M. C.. **As formigas-cortadeiras:** da bioecologia ao manejo. Viçosa: UFV, 2011.

OLIVEIRA, S. S.; CAMPOS, T.; SEBBENN, A. M.; OLIVEIRA, M. V. N.. Using spatial genetic structure of a population of Swietenia macrophylla King to integrate genetic diversity into management strategies in Southwestern Amazon. **For**

Ecol Manage, v.464, 2020. DOI: https://doi.org/10.1016/j.foreco.2020.118040

DIEHL-FLEIG, E.. **Formigas:** organização social e biologia comportamental. São Leopoldo: Unisinos, 1995

DINARDO-MIRANDA, L. L.; FRACASSO, J. V.. Variabilidade espacial e temporal de populações de nematóides parasitos de plantas em cana-de-açúcar. **Bragantia**, v.69, p.39-52, 2010. DOI: https://doi.org/10.1590/S0006-87052010000500006

DIONISIO, L. F. S.; LIMA, A. C. S.; MORAIS, E. G. F.; CORREIA, R. G.; SANTOS, A. V. F.; XIMENES, C. K. S.. Distribuição espacial de metamasius hemipterus (coleoptera: curculionidae) em plantio de dendê (elaeis guineensis jacq) em Roraima. **Agro@mbiente**, v.9, p.327-336, 2015. DOI: https://doi.org/10.18227/1982-8470ragro.v9i3.2517

DLUSSKIJ, G. M.. **Muravji roda Formica**. Moskva: Nauka, 1967.

DOLÁCIO, C. J. F.; KAZAMA, V. S.; SCHMITZ, R.; CORTE, A. P. D.; COSTA, L. R. R.; MACIEL, M. N. M.. Does using soil chemical variables in cokriging improve the spatial modelling of the commercial wood volume of Brazilian mahogany in an Amazonian agroforestry system?. **Comput Electron Agric**, v.180, 2021. DOI: https://doi.org/10.1016/j.compag.2020.105891

FARIAS, P. R. S.; HARADA, A. Y.; LIMA, B. G.; SALES, T. M.; SILVA, A. G.; SOUZA, B. H. S.. Mapping azteca barbifex forel (hymenoptera: formicidae) dispersal in georeferenced orange (citrus sinensis [l.] osbeck) orchard in the eastern Amazon, Brazil**. Insectes Soc**, v.65, p.345-350, 2018. DOI: https://doi.org/10.1007/s00040-018-0610-2

FARIAS, P. R. S.; ROBERTO, S. R.; LOPES, J. R. S.; PERECIN, D.. Geostatistical characterization of the spatial distribution of Xylella fastidiosa sharpshooter vectors on citrus. **Neotrop Entomol**, v.33, n.1, p.13-20, 2004. DOI: https://doi.org/10.1590/S1519-566X2004000100004

FROUZ, J.; RYBNÍČEK, M.; CUDLÍN, P.; CHMELÍKOVÁ, E.. Influence of the wood ant, Formica polyctena, on soil nutrient and the spruce tree growth. **Journal of Applied Entomology**, v.132, p.281-284, 2008. DOI: https://doi.org/10.1111/j.1439-0418.2008.01285.x

FROUZ, J.; HOLEC, M.; KALCIK, J.. The effect of Lasius niger (Hymenoptera, Formicidae) ant nests on selected soil chemical properties. **Pedobiologia**, v.47, p.205-212, 2003. DOI: https://doi.org/10.1078/0031-4056-00184

GOLDEN SOFTWARE. **Training guide**. Colorado, 2012.

GOMES, J. M.; SILVA, J. C. F.; VIEIRA, S. B.; CARVALHO, J. O. P.; QUADROS, L. C. L.; QUEIROZ, W. T.. Schizolobium parahyba var. amazonicum (Huber ex Ducke) Barneby can be used in enrichment planting in gaps caused by logging in Amazonia. **Ciência Florestal**, v.29, p.421-428, 2019. DOI: https://doi.org/10.5902/198050984793

GROGAN, J.; VERÍSSIMO, B. P.. **Mogno na Amazônia Brasileira**: ecologia e perspectivas de manejo. Belém: Imazon, 2022.

IBGE. **Instituto Brasileiro de Geografia e Estatística**, 2016.

LASMAR, O.; ZANETTI, R.; SANTOS, A.; FERNANDES, B. V.. Use of geostatistics to determine the spatial distribution and infestation rate of leaf-cutting ant nests (hymenoptera: formicidae) in eucalyptus plantations. **Neotrop Entomol**, v.41, p.324-332, 2012. DOI: https://doi.org/10.1007/s13744-012-0040-1

LOPES, J. C. A.; JENNINGS, S. B.; MATNI, N. M.. Planting mahogany in canopy gaps created by commercial harvesting. **For Ecol Manage**, v.255, n.2, p.300-307, 2008. DOI: https://doi.org/10.1016/J.FORECO.2007.09.051

MALOZEMOVA, L. A.; KORUMA, N. P.. O vljaniji muravjev na počvu. **Ekologia**, v.4, p.98-101, 1973.

MENDONÇA, L. A.. **Geoestatística na amostragem sequencial de ninhos de formigas cortadeiras em eucaliptais em região de Mata Atlântica**. Lavras: UFL, 2008.

NEVES, R. L. P.; SCHWARTZ, G.; LOPES, J. C. A.; LEÃO, F. M.. Post-harvesting silvicultural treatments in canopy logging gaps: medium-term responses of commercial tree species under tending and enrichment planting. **For Ecol Manage**, v.451, 2019. DOI: https://doi.org/10.1016/j.foreco.2019.117521

OLIVEIRA, P. S.; GALETTI, M.; PEDRONI, F.; MORELLATO, P.. Seed cleaning by micocepurus goeldii ants (attini) facilitates germination in hymenaea courbaril (caesalpiniaceae). **Biotropica**, v.27, p.518-522, 1995.

PASSOS, L.; OLIVEIRA, P. S.. Interactions between ants, fruits and seeds in a restinga forest in south-eastern Brazil**. J Trop Ecol**, v.19, p.261-270, 2003. DOI: https://doi.org/10.1017/S0266467403003298

PINHO, R. C. P.; FARIAS, P. R. S.; RODRIGUES, K. C. V.; TINÔCO, R. S.; SANTOS, A. V. F.; MARSSENA, R. T. P.. Distribuição espacial de rhynchophorus palmarum em palma de óleo no estado do Pará, Amazônia. **Rev Bras Ciênc Agrár**, v.59, p.22-31, 2016. DOI: https://doi.org/10.5039/agraria.v15i1a5683

RAFAEL, J. A.; MELO, C. A. R.; CARVALHO, C. J. B.; CASARI, A. S.; CONSTANTINO, R.. **Insetos do Brasil:** diversidade e taxonomia. Ribeirão Preto: Holos, 2012.

SANTINI JUNIOR, L.; FLORSHEIM, S. M. B.; TOMMASIELLO FILHO, M.. **Anatomia e Identificação da Madeira de 90 Espécies Tropicais comercializadas em São Paulo.** São Paulo: Atena, 2021.

SANTOS, J. O. P.; P. FILHO, O.; SOUZA, M. D.; DORVAL, A.. Preferência de Atta laevigata F. Smith, 1858 Hymenoptera: Formicidae) por diferentes espécies e híbridos de eucaliptos. **Rev Agric**, v.90, p.42-53, 2015.

SEFA. **Portaria SEFA 704/2015**. 2015

SCHWARTZ, G.; FALKOWSKI, V.; PEÑA-CLAROS, M.. Natural regeneration of tree species in the Eastern Amazon: Short-term responses after reduced-impact logging. **For Ecol Manage**, v.385, p.97-103, 2017. DOI: https://doi.org/10.1016/j.foreco.2016.11.036

SCHOWALTER, T. D.. **Insect Ecology:** an ecosystem approach. New York: Academic Press, 2006.

SILVA, A. G.; FARIAS, P. R. S.; BOIÇA JÚNIOR, A. L.; CORREIA, R. G.; SILVA, J. B.; RODRIGUES, N. E. L.. Análise espacial da mosca-negra-dos-citros em um pomar de citros utilizando a geoestatística. **Rev Agric**, v.6, n.3, p.102-114, 2011. DOI: https://doi.org/10.14295/CS.v6i3.408

SOARES, J. R. S.; SILVA P. J.; ARAÚJO, V. C. R.; ARAÚJO, T. A.; RAMOS, R. S.; PICANÇO, M. C.; ZANUNCIO, J. C.. Spatiotemporal dynamics and natural mortality factors of myzus persicae (sulzer) (hemiptera: aphididae) in bell pepper crops. **Neotrop Entomol**, v.49, p.445-455, 2020. DOI: https://doi.org/10.1007/s13744-020-00761-2

SOSSAI, M. F.; ZANUNCIO, J. C.; LEITE, H. G.; ZANETTI, R.; SERRÃO, J. E.. Transects to estimative the number of leaf-cutting ant nests (hymenoptera: formicidae) in eucalyptus urophylla plantations. **Sociobiology**, v.46, p.667-676, 2005.

SUJIMOTO, F. R.; COSTA, C. M.; ZITELLI, C. H. L.; BENTO, J. M. S.. Foraging activity of leaf-cutter ants is affected by barometric pressure. **Ethology**, v.126, n.3, 2019. DOI: https://doi.org/10.1111/eth.12967

TRIPLEHORN, C. A.; JOHNSON, N. F.. **Introduction to the study of insects**. São Paulo: Cengage Learning, 2011.

VASCONCELOS, H. L.; CHERRET, J. M.. The effect of wilding on the selection of leaves by the leaf-cutting ant atta laevigata. **Entomol Exp Appl**, v.78, p.215-220, 1996.

VIEIRA, S. R.; HATFIELD, J. L.; NIELSEN, D. R.; BIGGAR, J. W.. Geostatistical theory and application to variability of some agronomical properties. **Hilgardia**, v.51, p.1-75, 1983. DOI: https://doi.org/10.3733/hilg.v51n03p075

VIEIRA, S. B.; CARVALHO, J. O. P.; GOMES, J. M.; SILVA, J. C. F.; RUSCHEL, A. R.. Is cedrela odorata L. A species with potential to be used in post-harvesting silviculture in the Brazilian Amazonia? **Ciênc Florest**, v.28, n.3, p.1230-1238, 2018. DOI: https://doi.org/10.5902/1980509833361