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# CANOPY COVER DYNAMICS, SOIL TEMPERATURE AND MOISTURE IN AGROFORESTRY SYSTEMS IN THE WEST OF PARÁ

ABSTRACT: Considering the importance of the forest component in agroforestry systems (AFSs), this study aimed to analyze the dynamics of canopy cover, temperature and soil moisture in three agroforestry systems, which have different arrangements, having in common the production of black pepper (*Piper nigrum* L.), in Belterra and Mojuí dos Campos, in Pará, inserted in properties of family farmers. Data collection for moisture, soil temperature and canopy cover was performed monthly for nine months (April to December/2017). These measurements were performed at six points in the rows and between the rows of perennial planting in each system. It was concluded that the canopy cover within the evaluated systems can be considered, in AFSs 1 and 2, as a factor that regulates the amount of light that reaches the system, influencing the soil moisture, both in the row and between the rows. However, soil temperature was the variable that suffered the least interference and that interfered least in the other variables analyzed.

KEYWORDS: Microclimate, Treecrops, Silviculture.

# DINÂMICA DA COBERTURA DE DOSSEL, TEMPERATURA E UMIDADE DO SOLO EM SISTEMAS AGROFLORESTAIS NO OESTE DO PARÁ

RESUMO: Considerando a importância do componente florestal nos sistemas agroflorestais (SAFs) este trabalho objetivou analisar a dinâmica da cobertura de dossel, temperatura e umidade do solo em três sistemas agroflorestais, que dispõem de arranjos diferentes, tendo em comum a produção de pimenta-do-reino (*Piper nigrum* L.), em Belterra e Mojuí dos Campos, no Pará, inseridos em propriedades de agricultores familiares. A coleta de dados para umidade, temperatura do solo e a cobertura do dossel foi realizada mensalmente durante nove meses (abril a dezembro/2017). Estas medições foram realizadas em seis pontos nas linhas e nas entrelinhas de plantio perene de cada sistema. Concluiu-se que a cobertura de dossel dentro dos sistemas avaliados pode ser considerada, nos SAFs 1 e 2, como um fator que regula a quantidade de luz que chega no sistema, influenciando na umidade do solo, tanto na linha quanto na entrelinha. No entanto, a temperatura do solo foi a variável que menos sofreu interferência e que menos interferiu nas demais variáveis analisadas.

PALAVRAS-CHAVE: Microclima, Cultivos arbóreos, Silvicultura.

## DINÁMICA DE CUBIERTA DE DOSEL, TEMPERATURA Y HUMEDAD DEL SUELO EN SISTEMAS AGROFORESTALES DEL OESTE DE PARÁ

RESUMEN: Considerando la importância del componente forestalenlos sistemas agroforestales (SAF), este estudiotuvo como objetivo analizar la dinámica de la cobertura deldosel, la temperatura y lahumedaddelsueloentres sistemas agroforestales, que tienen diferentes arreglos, teniendo em comúnlaproducción de pimienta negra (*Piper nigrum* L) em Belterra y Mojuí dos Campos, en Pará, insertos em propiedades de agricultores familiares. La recolección de datos de humedad, temperatura delsuelo y cobertura deldosel se realizo mensualmente durante nueve meses (abril a diciembre/2017). Estas mediciones se realizaronen seis puntos de lossurcos y entre lossurcos de siembra perene en cada sistema. Se concluyó que la cobertura deldosel dentro de los sistemas evaluadospuede ser considerada, em los SAF 1 y 2, como um factor que regulalacantidad de luz que llega al sistema, influyendo em lahumedaddelsuelo, tanto em hilera como entre hileras. Sin embargo, la temperatura delsuelofuelavariable que menos interferênciasufrió y la que menos interfirió em lasdemásvariablesanalizadas.

PALABRAS CLAVES: Microclima, Cultivos arbóreos, Silvicultura.

## INTRODUCTION

Agroforestry systems (AFS) are a set of techniques that intentionally combine, in the same unit of area, forest species (trees, palm trees, bamboo trees) with agricultural crops, with or without the presence of animals, to offer goods and services on a sustainable basis from the established interactions (SILVA, 2013). This type of cultivation has been listed as a more balanced production system with the possibility of mitigating greenhouse gases (AZEVEDO et al., 2016). It is also indicated as a strategy to strengthen socio-environmental resilience, providing less dependence on external inputs (ALMEIDA; MAY, 2016) reduction of soil erosion, increase in carbon stock and long-term environmental gains, when compared to monoculture (MARTORANO et al., 2016).

These systems are characterized, among many other forms of cultivation in the Amazon region, as one of the most important components of the mosaic of land use and land cover present in this region, the emphasis on this modality is justified by its contribution to ecosystem services provided (BOLFE et al., 2012). Agricultural activities carried out on the soil, to obtain economic services, directly influence the process of water infiltration into the soil (SILVA, 2012) where changes in land use can modify biophysical and biogeochemical parameters, as well as latent and sensible heat fluxes, which are intrinsically associated with the hydrology and transpiration of vegetation (DEBORTOLI, 2013).

The absorption of water by the soil depends on its texture and structure and densified soils result in erosion and surface runoff of water, in the same way that the thermal properties of the soil are the result of a set of factors which include its texture and chemical composition, which makes tropical soils to be considered an ecosystem of multiple factors, which interconnected make an organized structure work (CARNEIRO et al., 2014; PRIMAVESI, 2016), Canopy cover tends to provide positive effects on certain species cultivated in intercropped systems, for example, increasing the production of secondary compounds and biomass cultivated in this situation, being favored by higher shading rates (BORGES et al., 2019).

The knowledge of the dynamics of the canopy cover is an important variable to point out which arrangements present the best working conditions, considering the thermal comfort provided by the shade of the trees. In addition to this labor factor, the canopy behavior is one of the factors for the insertion or exclusion of crops in intercropped systems, which will influence the decision-making by producers or technical assistance providers. Thus, considering that the AFSs have the role of uniting species with different functions and that the canopy cover has a decisive role in these relationships, this work aims to analyze the dynamics of canopy cover, temperature and soil moisture in three agroforestry systems in western Pará.

## MATERIAL AND METHODS

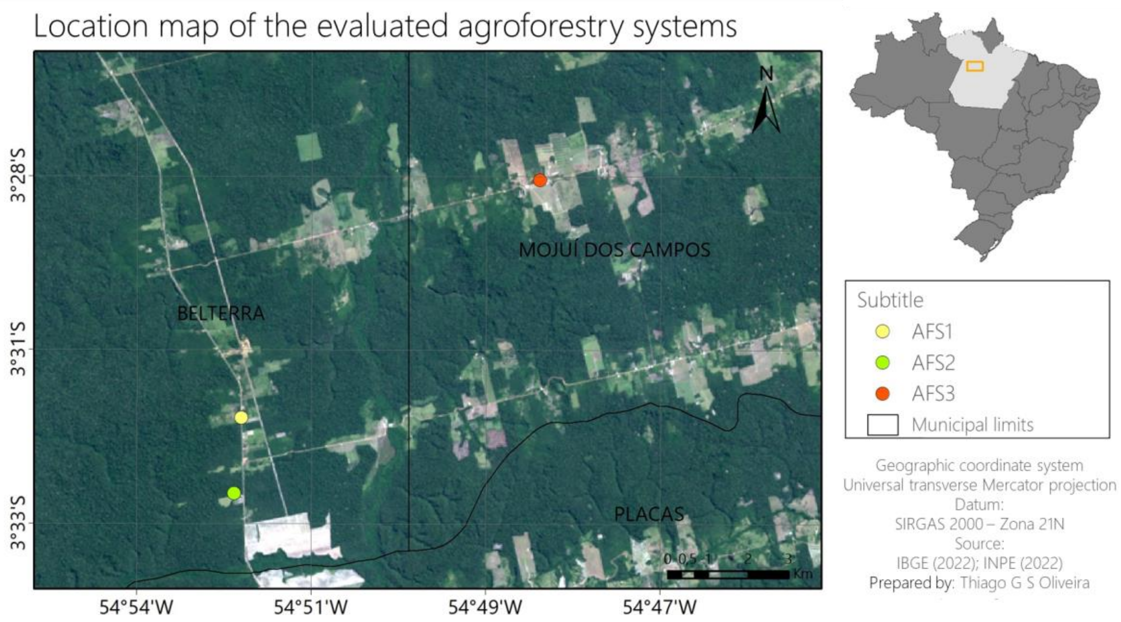
### CHARACTERIZATION OF THE AREA

The study was carried out in the municipalities of Belterra and Mojuí dos Campos, in the state of Pará. The climate classification in the region is of the Am type (Köppen) with an average altitude of 130 m, average temperature above $26^0$ C and annual precipitation of 2,200 to 2,500 mm (ALVARES et al., 2013) and soil of the Dystrophic Yellow Latosol type (HENRIQUES et al., 2008; IBGE, 2012).

The AFSs were implemented by family farmers between 2007 and 2013 with the support of the Technical Assistance and Rural Extension Company of the State of Pará (Assistência Técnica e Extensão Rural do Estado do Pará – EMATER), as a strategy to strengthen family income and diversify production. In addition to EMATER supporting the implementation of AFSs, it carries out periodic visits to these three systems. The choice of these AFSs as an area of study was motivated by the indication of EMATER, because they are representative systems in the region and because they are producers that allow the entry of researchers in their areas, as well as presenting affinity with the exchange of knowledge with outside people.

The study was carried out in three intercropped systems (Figure 1) that have different arrangements, having in common the production of black pepper (Piper nigrum L.), as the main economic product.

Figura 1. Location of agroforestry systems, municipality of Belterra and Mojuí dos Campos, Pará.




Source: Prepared by the authors

Based on soil fertility analyzes performed in these systems by Silva et al. (2020) in 2016, System 1 has an organic matter content equal to 21.40 g/Kg, phosphorus equal to 4 mg/dm3 and potassium equal to 27 mg/dm3. System 2 has an organic matter content equal to 22.23 g/Kg, phosphorus equal to 5 mg/dm3 and potassium equal to 36 mg/dm3, and System 3 has an organic matter content equal to 12.25 g/Kg, phosphorus equal to 9 mg/dm3 and potassium equal to 18 mg/dm3.

The agroforestry systems evaluated are configured as systems with dynamic management, which according to Campos (2022), are characterized by being composed of dynamic components, whose entry and exit is motivated by market fluctuation, increase and decrease in prices of certain products, or also by ecological aspects of the selected species, such as adaptability of cultivars or emergence of diseases or pests.

The first system (AFS1) corresponds to an area of 1.5 hectares on the side of the Cuiabá-Santarém Highway (BR 163), in the municipality of Belterra. It was implemented in 2012, where cassava (*Manihot* sp.) was planted in the first two years, between the rows of perennial and semi-perennial plantations. The arrangement of this system is composed of Cumaru (*Dipteryx spp.*) + Black pepper (*Piper nigrum* L) + Banana (*Musa spp.*) + Cupuaçu (*Theobroma grandiflorum* (Willd. Ex Spreng.) K. Schum) + Açaí (*Euterpe oleracea Mart*.) and Graviola (*Annona muricata L*.). The history of use of the area includes the raising of cattle for five years before the implementation of the system. Soil fertilization for AFS implantation was carried out with the application of 20 g of mineral fertilizer (NPK 10-28-20) per cover on each seedling for all species, being reapplied once a year within the limits of the canopy projection. There was also the application of organic fertilization with cattle and chicken manure in the hole during planting and once a year as part of the management of the system, being carried out in the month of the beginning of the rains (December or January). The amount of organic fertilizer applied in this process was not informed by the producers, they usually do not control the addition of this material when planting. The producer performed pruning in Cumaru and mowing in the entire area of cultivation of the system, leaving the crop residues as ground cover (Figure 2).

The second system (AFS2) has an area of 0.30 hectare, is also located on the side of the Cuiabá-Santarém Highway (BR 163), in the municipality of Belterra, and was created based on a natural regeneration area composed predominantly of taperebá (Spondias mombin L.), being this species used as a live tutor (support for fixing plants) to support the black pepper (*Piper nigrum* L.), inserted starting from the of year 2007 (Figure 3).

Figure 2. Sketch of the arrangement of forest species and photos of the row and between rows, of the agroforestry system implemented in Belterra, Pa.


Source: Prepared by the authors

As this system presented a random distribution as a function of taperebá regeneration, the collections made under the canopy were adopted as a row, and the collections made outside the canopy projection of the taperebá species were adopted as between rows.

The third system (AFS3) is located in an area of 1 hectare, located on the Galiléia crossroads, perpendicular to the Cuiabá-Santarém Highway (BR 163), in the municipality of Mojuí dos Campos. This area was used for cattle raising for fifteen years prior to the implementation of the evaluated plantation. In 2012, in a consortium form, it was implemented the cumaru (*Dipteryx odorata* (Aublet.) Willd.), black pepper (*Piper nigrum* L.), and moringa

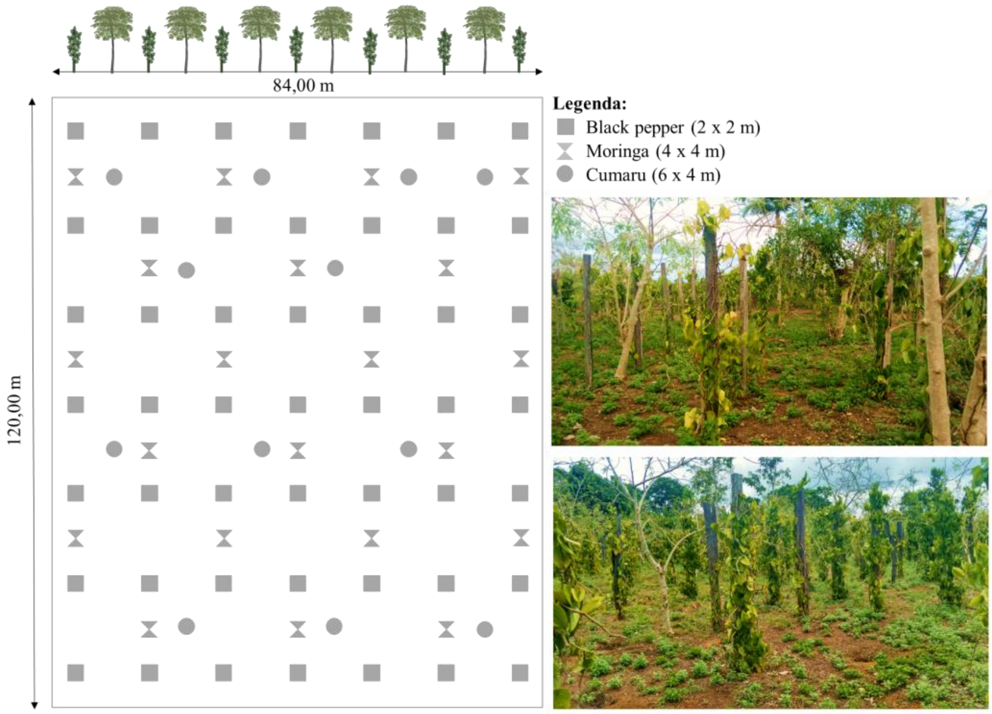
(*Moringa oleifera* Lam.), being that in the first three years there were annual plantations of cassava (*Manihot* sp) and pineapple (*Ananas* sp) (Figure 4).

Figure 3. Sketch of the arrangement of forest species and photos of the row and between rows, of the agroforestry system implemented in Belterra, Pa.


Source: Prepared by the authors

For planting, fertilizing was made from compost, produced by the producer himself using materials such as corn husk, sugarcane bagasse, banana bunches and peels and animal manure. This compost was applied directly to the pit and, during maintenance, fertilization was carried out with fresh biomass from the deposition of spontaneous plants, grasses and moringa branches in the soil, after mowing and pruning. The producer also fertilized the black pepper in January 2017, with NPK in formulation 18-18-18, in order to stimulate the growth of the species, and in February of the same year NPK was applied in formulation 10- 28-20 to stimulate fruiting. Figure 2 presents the graphic scheme of the species arrangements in the evaluated AFSs.

Figure 4. Sketch of the arrangement of forest species and photos of the row and between rows, of the agroforestry system implemented in Mojuí dos Campos, Pa.




Source: Prepared by the authors

## DATA COLLECTION AND ANALYSIS

The climatological variables used in this study were obtained from the Meteorological Database for Teaching and Research (BDMEP), made available by the National Institute of Meteorology (INMET, 2017), considering information for the conventional climate station of Belterra.Agroforestry systems are within a 100 km radius of the climatological station.

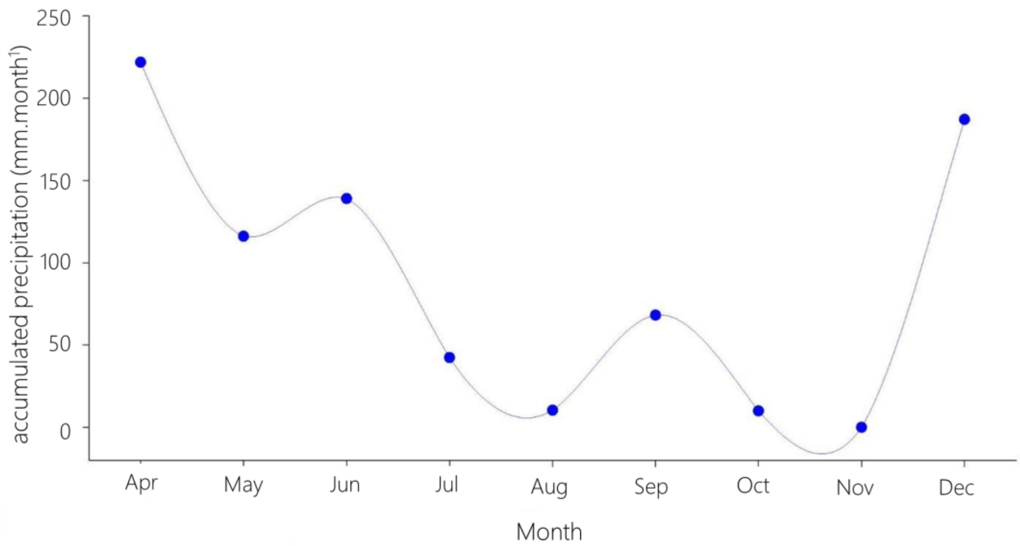
The research period for the canopy cover and soil moisture variables lasted nine months (April to December 2017), for the soil temperature it lasted eight months (May to December 2017). In April 2017, for AFS1, temperature data was not collected due to problems with the measurement device, but this system was maintained due to the significance of the data obtained in the other months and for the other variables evaluated. The variables soil moisture and temperature obtained with the Thermo-Hygrometer device ITHT 2250, introduced into the soil at a depth of 2 cm, instantly providing the values, and the canopy coverage was obtained using the Spherical Densiometer device according to the methodology proposed by Suganuma et al. al. (2008). The measurements of humidity, temperature and canopy coverage were performed at six points in the planting rows and between rows of each system, at non-fixed times, totaling twelve sampling points per month.

The data referring to the variables canopy cover (CD), soil temperature (TS) and soil moisture (US) was submitted to the Shapiro Wilk test to evaluate normality, and the data that did not show normality was logarithmized and, once normality was verified, the data was submitted to analysis of variance followed by t test to compare the variables in row and between rows in each system, followed by Tukey test to compare the means throughout the evaluation period. Finally, Pearson's correlation coefficient was used to assess the dependence between the variables. All data was tabulated in the Microsoft Excel program and analyzed in the Assistant 6.2 program.

## RESULTS AND DISCUSSION

During the collection period, the monthly accumulated precipitation varied with a maximum of 250.00 mm.month-1 in March, extending until June, and a minimum of 0.00 in November, starting in August (Figure 5) Since precipitation is a factor of direct interaction with the soil, when the average of US is evaluated during the sampling period, it is noted that in the rainy season (April to July) the three systems had, on average, a higher percentage (43.3 %) of humidity than in the dry period, which was 40.7 %, for the months of August to December (Figure 2, 3 and 4) regardless of the collection position at planting.

Figure 5: Monthly accumulated rainfall from April to December 2017, in the study area.




Source: INMET, 2017. Prepared by the authors

CANOPY COVER (CD)

The CD results for AFS1 indicated that there is no need for intervention to open the canopy aiming at the insertion of new species, due to the fact that this system is already diverse. The CD in the row ranged from 18.0% (July) to 51.1% (December) and in between rows ranged from 9.7% (August) to 32.6% (December). When comparing the planting row and between rows, a significant difference was observed for the months of April, July, August, September, October and December,always having higher averages in the planting rows (Table 1A).

Considering the diversity presented by AFS1, the CD results indicate that there is no need to open the canopy for the insertion of new species or individuals. In AFS2 the CD in the row ranged from 9.4% (September) to 44.0% (December), while between the rows the averages ranged from 4.3% (July) to 46.3% (December). For this variable, when the averages were compared in row and between rows, no statistically significant difference was observed. However, when compared over time, in isolation, in rows and between rows, they differed statistically, with the months of April and December having the highest percentages of CD and also of precipitation. It is noteworthy that the CD averages, both in the row and between rows, showed similar behavior, decreasing between the months of June and October, with a subsequent increase in CD in the following months (Table 1B).

While in AFS3 the CD in the row ranged from 5.7% (September) to 21.1% (December) and in the between rows it ranged from 2.6% (June) to 16.5% (December). For this system, no statistical difference was found when comparing the row and between rows of planting (Table 1C). AFS3 has one of the lowest percentages of CD, which may be associated with the crown characteristics of the main tree species in this system (moringa) which, according to field observations, presents a canopy with few leaves and small size. This fact can be explained by the pruning that is carried out in the species aiming at the commercialization of the leaves. In addition, it was also observed that in June, at the peak of flowering, the crown of this species reduced the amount of leaves, influencing CD values.

The variation in the CD of AFS2 may be related to the only species of the forest component of this system, the taperebá, which is a deciduous plant, with loss of its leaves in the summer (GUIMARÃES et al., 2021). It was observed that the taperebá in the months of July to August presented leaf fall, which reflected in the reduction of the CD in this period, and followed with regrowth of leaves in the month of September, causing again the increase of CD from this month. This observation reveals the importance of diversification in the choice and introduction of tree components in AFSs, so as not to contain only deciduous species that expose the system to direct radiation during the dry season.

Table 1. Percentage of canopy cover, temperature and soil moisture in the row and between rows, in the 3 agroforestry systems, from April to December 2017 in Belterra and Mojuí dos Campos, Pará.

| | apr/17 | may/17 | jun/17 | jul/17 | aug/17 | sep/17 | oct/17 | nov/17 | dec/17 |
|---|---|---|---|---|---|---|---|---|---|
| **AFS 1** | | | | | | | | | |
| **Canopy cover (%)** | | | | | | | | | |
| Rows | 31,2 ±5,9 Abc | 19,4 ± 2,6 Ac | 21,3 ± 3,5 Abc | 18,0 ± 8,9 Ac | 19,8 ± 6,8A c | 26,7 ± 6,4 Abc | 28,4 ± 11,5 Abc | 39,7 ± 18,3 Aab | 51,1 ± 17,5 Aa |
| Between the rows | 22,4 ± 5,9 Babc | 14,7 ± 6,7 Abcd | 15,6 ± 5,6 Abcd | 13,0 ± 2,3 Bcd | 9,7 ± 3,9 Bd | 15,3 ± 7,6 Bbcd | 18,0 ± 6,1 Abcd | 23,4 ± 5,8 Aab | 32,6 ± 4,4 Ba |
| **Temperature (ºC)** | | | | | | | | | |
| Rows | _ | 26,8 ± 0,6 Ad | 27,9 ± 2,7 Acd | 26,4 ±1,3 Ad | 27,7 ± 0,9 Acd | 33,4 ± 1,9 Aa | 32,6 ± 1,7 Aab | 29,9 ± 0,9 Abc | 28,5 ± 1,0 Acd |
| Between the rows | _ | 27,2 0,9 Ac | 28,2 ± 1,4 Ac | 27,6 ± 1,6Ac | 28,7 ± 1,4 Abc | 35,2 ± 4,0 Aa | 32,3 ± 1,7 Aab | 30,7 ± 2,2 Abc | 29,5 ± 1,1 Abc |
| **Moisture (%)** | | | | | | | | | |
| Rows | 58,0 ± 3,2 Aab | 65,7 ± 1,4 Aa | 51,2 ± 3,5 Abc | 41,8 ± 5,7 Ad | 44,8 ± 7,7 Acd | 31,0 ± 2,1 Ae | 37,3 ± 3,9 Ade | 42,3 ± 2,8 Ad | 55,2 ± 2,7 Ab |
| Between the rows | 57,0 ± 4,1 Ab | 66,7 ± 2,7Aa | 53,3 ± 3,1 Abc | 42,0 ± 5,8 Ade | 46,7 ± 7,2 Acd | 32,3 ± 2,0 Af | 36,0 ± 3,8 Aef | 42,7 ± 2,8 Ade | 54,8 ± 1,8 Ab |
| **AFS 2** | | | | | | | | | |
| **Canopy cover (%)** | | | | | | | | | |
| | apr/17 | may/17 | jun/17 | jul/17 | aug/17 | sep/17 | oct/17 | nov/17 | dec/17 |
| Rows | 32,9 ± 9,5 Aab | 20,1 ± 3,8 Abc | 14,6 ± 6,1 Ac | 10,9 ± 4,8 Ac | 14,0 ± 8,9 Ac | 9,4 ± 4,5 Ac | 15,6 ± 6,6 Ac | 33,3 ± 8,6 Aab | 44,0 ± 8,3 Aa |
| Between the rows | 36,7 ±10,4 Aa | 20,8 ± 1,6 Ab | 9,2 ± 4,9 Abc | 4,3 ± 5,4 Ac | 6,4 ± 2,4Ac | 5,9 ± 5,5 Ac | 13,9 ± 5,0 Abc | 35,9 10,5 Aa | 46,3 ± 8,6 Aa |
| **Temperature (ºC)** | | | | | | | | | |
| Rows | 29,0 ± 0,2 Ac | 30,0 ± 1,2 Ac | 30,1 ± 1,7 Ac | 34,1 ± 2,6 Aab | 36,4 ± 3,7 Aa | 35,3 ± 1,2 Aa | 32,0 ± 0,6 Abc | 30,4 ± 1,1 Ac | 28,8 ± 0,4 Ac |
| Between the rows | 29,3 ± 1,0 Abc | 28,5 ± 0,9 Bc | 29,5 ± 1,7 Abc | 35,2 ± 3,9 Aa | 32,8 ± 2,1 Aab | 35,7 ± 0,9 Aa | 30,6 ± 1,0 Bbc | 31,8 ± 4,1 Aabc | 29,4 ± 1,5 Abc |
| **Moisture (%)** | | | | | | | | | |
| Rows | 58,3 ± 4,5 Aab | 59,8 ± 4,5 Aa | 42,3 ± 4,6 Ade | 25,3 ± 3,7 Ag | 26,8 ± 7,9 Ag | 29,5 ± 0,5 Afg | 44,5 ± 1,9 Acd | 34,8 ± 2,9 Aef | 51,3 ± 2,9 Abc |
| Between the rows | 58,7 ± 5,8 Aab | 59,8 ± 3,9 Aa | 42,7 ± 4,7 Ade | 26,0 ± 5,3 Ag | 25,0 ± 6,5 Ag | 29,7 ± 0,5 Ag | 45,3 ± 0,8 Acd | 35,5 ± 1,9 Aef | 51,5 ± 1,6 Abc |
| **AFS 3** | | | | | | | | | |
| **Canopy cover (%)** | | | | | | | | | |
| | apr/17 | may/17 | jun/17 | jul/17 | aug/17 | sep/17 | oct/17 | nov/17 | dec/17 |
| Rows | 17,5 ± 2,9 Aab | 16,1 ± 4,7 Aab | 13,9 ± 11,7 Aab | 13,0 ± 10,3 Aab | 6,1 ± 3,1 Ab | 5,7 ± 5,0 Ab | 10,4 ± 7,2 Aab | 16,8 ± 4,9 Aab | 21,1 ± 12,3 Aa |
| Between the rows | 12,5 ± 5,5 Aab | 9,4 ± 4,2 Bab | 2,6 ± 3,6 Bb | 2,9 ± 2,0 Bb | 2,9 ± 4,3 Ab | 2,8 ± 4,3 Ab | 8,7 ± 9,1 Aab | 11,1 ± 4,3 Aab | 16,5 ± 11,6 Aa |
| **Temperature (ºC)** | | | | | | | | | |
| Rows | 33,9 ± 1,7 Acd | 32,6 ± 1,6 Acd | 34,5 ± 3,9 Acd | 41,6 ± 2,8 Aa | 36,6 ± 2,4 Abc | 34,9 ± 2,8 Acd | 39,7 ± 2,9 Aab | 32,3 ± 1,2 Bcd | 31,4 ± 0,7 Ad |
| Between the rows | 33,8 ± 2,8 Abc | 31,5 ± 1,2 Ac | 38,3 ± 3,2 Aab | 42,1 ± 4,2 Aab | 37,7 ± 3,2 Aab | 34,7 ± 0,8 Aa | 40,9 ± 3,3 Aa | 33,7 ± 0,9 Abc | 31,7 ± 0,7 Ac |
| **Moisture (%)** | | | | | | | | | |
| Rows | 49,8 ± 6,8 Aab | 44,0 ± 3,8 Ab | 32,5 ± 5,1 Ac | 20,8 ± 6,1 Ad | 34,3 ± 3,2 Ac | 34,3 ± 0,5 Ac | 27,2 ± 1,5 Acd | 51,7 ± 1,8 Aa | 53,8 ± 2,0 Aa |
| Between the rows | 51,3 ± 6,8 Aab | 45,7 ± 5,6 Ab | 34,3 ± 6,1 Ac | 20,3 ± 5,5 Ad | 34,3 ± 2,9Ac | 34,2 ± 0,4 Ac | 26,8 ± 1,2 Acd | 51,8 ± 2,3 Aab | 54,5 ± 1,9 Aa |

Caption: Averages followed by the same letter do not differ statistically from each other, capital letters for comparison in the columns by the t test at 5% of significance and lowercase letters for comparison in the row by the tukey test at 5% of probability.

Source: Prepared by the authors.

SOIL TEMPERATURE (TS)

On the amplitude of soil temperature (TS) observed in the planting rows and between rows of the perennial species in AFS1 (Table 1A) which in the row had an amplitude between 26.4 °C (July) to 33.4 °C (September) and in the between rows it ranged from 27.2 °C (May) to 35.2 °C (September) these amplitudes showed a statistical difference between them. It can be noticed that the TS presented little variation when comparing the planting row and between rows, not differing statistically from each other. The average in the perennial planting row of the system was 27 °C, while in the inter-crop row it was 28 °C.

As for the temperature in AFS3, it varied from 29.0 °C (December) to 36.4 °C (August) on the row and from 28.5 °C (May) to 35.7 °C (September) on the between rows. For this variable, it was observed that the averages when compared in the row and between rows were statistically equal to each other, except for the month of May where the averages 30.0 °C (row) and 28.5 °C (between rows) statistically differed (Table 1C). When analyzed over the period on the row, the highest averages from July to September were considered equal to each other and statistically differed from the averages obtained in the other months. In the between rows, the average values presented a somewhat similar behavior, with the highest averages situated from July to September and November considered equal to each other and differing significantly from the other months.

When observing the dynamics of AFS2 in which both TS and US were directly affected by the foliar fall of the tree component, it is understood that, when the system has greater canopy coverage, TS tends to reduce because it is receiving less solar radiation. This is also observed in studies in native forests, where the temperature is higher where there is an incidence of solar radiation, mainly in the more superficial layers of the soil (CARNEIRO et al., 2013).

The TS in AFS 3 on row ranged from 31.4 °C (December) to 41.6 °C (July) and between rows ranged from 31.5 °C

(May) to 42.1 °C (July). When comparing planting rows and between rows, a statistical difference was observed only for the month of November with the highest average temperature between planting rows (Table 1C).

Considering the TS of the systems, it is understood that they exhibit temperatures close to ideal (AFS1) and ideal (AFSs 2 and 3) because, as exposed by Brancalion et al. (2010), when analyzing the optimal temperature for seed germination, for Amazonian species the soil temperature must be between 30 °C and 35 °C. This discussion is relevant when dealing with agroforestry systems, because in these environments it is inherent to the dynamics of removal and introduction of species, being necessary that these soils have conditions to provide the establishment of new plants.

In the AFS2, TS was influenced by the canopy cover together with the US, presenting an inverse behavior, given that, in the months of leaf fall of the tree component of the system (Taperebá), the TS presented an increase and in the month in which it began to show new leaves (month of September), the TS showed a decline (Table 1B). The temperature together with soil moisture are closely interconnected factors and, when properly managed, can provide increases in crop production (KNIES, 2010).

SOIL MOISTURE (US)

The US in the AFS1 ranged from 31.0% (September) to 65.7% (May) in the planting row and from 32.3% (September) to 66.7% (May) between rows. This variable did not present statistical differences in the averages when comparing the planting rows and between rows (Table 1A). When analyzing the precipitation graph (Figure 5) and the US data in the planting row and between rows (Table 1A), it is observed that in the month of November, without precipitation, the US was higher than the previous month (October), in which there was more precipitation. This fact may be influenced by the increase in canopy cover in November (Table 1A), which shows the importance of canopy cover to guarantee the US in periods of low rainfall.

Regarding humidity (%) in AFS 2, the highest averages both in the row (59.8±4.5) and between rows (59.8±3.9) were recorded in the month of May, which were considered statistically equal. In the row the average humidity throughout the evaluated period varied from 25.3% to 59.8%, and between rows it varied from 25.0% to 59.8%. The rows with the highest averages of US 58.3% and 59.8% observed in April and May, respectively, were considered equal to each other and statistically differed from the other averages obtained in the other months, in between rows, it is worth noting that AFS2 presented a reduction in the US in the month of July, a period in which there was also a reduction in the percentages of canopy coverage, which indicates that this variable contributes to the maintenance of US levels in the systems (Table 2 B).

The US in AFS3 on Row ranged from 20.8% (July) to 53.8% (December) and between rows ranged from 20.3% (July) to 54.5% (December). There was no statistical difference when comparing the row and between rows in any of the months (Table 1C). The same relationship between US and canopy cover observed in AFS1 (2A) can also be observed in AFS3, which presented lower soil moisture in the same month in which the canopy cover began to decrease (Figure 2A and 2C).

Thus, it is understood that the soil component is of great importance in AFSs, since its surface, with or without vegetation cover, is primarily responsible for the exchange and storage of thermal energy in terrestrial ecosystems (CARNEIRO et al. 2013). As well as the canopy cover that will influence the amount of solar energy available in the system, especially in the lower strata of intercropping.

CORRELATION OF VARIABLES

When evaluating the correlation between the variables, the AFS 1 shows a weak correlation for all variables with r values ranging from -0.06 to 0.07 (Table 2), indicating that variations in CD, US and TS have little influence on one another. In AFS2, the analysis shows that there was a moderate positive correlation between soil moisture and canopy cover (r=0.53), while in AFS3, there was a weak positive correlation for these two variables (r=0.41). These results indicate that soil moisture increases as canopy cover increases. In these two systems, the main tree components are Taperebá (AFS2) and Moringa (AFS3), which may have benefited US.

**Table 2.** Matriz de correlação de Pearson.

| Soil variables | AFS 1 | | | AFS 2 | | | AFS 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Canopy | Soil Temp. | Soil Moist. | Canopy | Soil Temp | Soil Moist. | Canopy | Soil Temp | Soil Moist. |
| Canopy | 1 | -0,06 | 0,07 | 1 | -0,5 | 0,53 | 1 | -0,34 | 0,41 |
| Soil Temp. | -0,06 | 1 | -0,6 | -0,5 | 1 | -0,64 | -0,34 | 1 | -0,69 |
| Soil Moist. | 0,07 | -0,6 | 1 | 0,53 | -0,64 | 1 | 0,41 | -0,69 | 1 |

Caption: AFS = Agroforestry system, Temp= Temperature, Moist = Moisture.

Source: Prepared by the authors

Soil moisture showed a moderate negative correlation with soil temperature in the three systems evaluated with r= -0.60 in AFS1, r= -0.64 in AFS2 and r= 0.69 in AFS3, showing that the temperature, unlike the canopy, does not have the ability to significantly influence this variable in the evaluated systems.

CONCLUSION

The canopy cover within the evaluated systems can be considered, in AFSs 2 and 3, as a factor that regulates the amount of light that reaches the system, influencing soil moisture, both in the row and between rows. Differently from the canopy cover, the soil temperature was the variable that suffered the least interference and that interfered least in the other variables analyzed.

It is also considered that in order to obtain more precise answers about the relationship between soil moisture and mulch on the soil, it would be necessary to carry out specific experiments for this purpose, considering that moisture is a variable influenced by several environmental factors.

For the AFS1, it is recommended to keep the conduction pruning on the cumaru component. In AFS2, where the Canopy Coverage did not indicate a significant difference throughout the year, the ideal would be to perform thinning in the Taperebá species, however, such intervention is characterized as an expensive service, thus suggesting the insertion of shade tolerant species for better use of the canopy cover conditions existing in this system.

In AFS 3, it is recommended that the pruning activities that are already carried out in Moringa are not intensified, considering that in the dry period it naturally loses its leaves, with this the intensification of pruning can influence a possible increase in temperature and lower humidity on the ground in this system.

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