Quantificação dos serviços ambientais em agroflorestas e áreas de monocultivo tradicional na zona da mata e no semiárido Pernambucano.

Quantifying environmental services in agroforestry and traditional monoculture areas in Pernambuco state, Brazil.

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Resumo: O presente estudo integrou medidas no solo, na vegetação, e dados espectrais para quantificar a provisão de serviços ambientais em áreas de agroflorestas e de monocultivos tradicionais nas regiões de Zona da Mata, Agreste e Sertão no Estado de Pernambuco, Brasil. Foram avaliadas 24 áreas, sendo quantificado estoques de carbono na vegetação e solo, bioindicadores do solo (ß-glicosidase e Aril-sulfatase), emissões de gases de efeito estufa do solo (CH_4, CO_2, NO_3), além disso utilizando imagens de drone determinou-se a temperatura ao nível do solo, índice de cobertura do solo. Os resultados apontam que agroflorestas acumulam mais carbono na biomassa que monocultivos. A atividade enzimática indica que solos de agroflorestas são mais resilientes para suportar as mudanças climáticas que em monocultivos. Os dados espectrais também revelaram que agroflorestas tem temperatura a altura do solo mais amena que cultivos tradicionais, com a vantagem de promover maior cobertura do solo e atividade fotossintética. Em conclusão, as agroflorestas maior volume de serviços ambientais seja em termos de estocagem de carbono, manutenção da vida do solo, maior ciclagem de nutrientes no ecossistema e melhor ambiência em escala local quando comparadas com áreas de monocultivo.

Palavras-chave: carbono; mudanças climáticas, agroecologia; bioindicadores do solo.

Keywords: carbon; climate change; agroecology; soil biodindicators.

Abstract: The study integrated soil, vegetation, and spectral data to quantify the provision of ecosystem services in agroforestry and monoculture crops in areas of the Zona da Mata, Agreste, and Sertão in the state of Pernambuco, Brazil. Twenty--four areas were evaluated, quantifying carbon stocks in vegetation and soil, soil bioindicators (ß-glucosidase and Aryl-sulfatase), soil greenhouse gas emissions (CH4, CO2, NO3). Using an RBG coupled in a drone we obtained the temperatu-

re at ground level, land cover, and photosynthesis index. The results indicate that agroforests accumulate more carbon from biomass than traditional crops. The enzymatic activity means that agroforestry soils are more resilient to climate change than monocultures. The spectral data also revealed that agroforestry has a milder temperature at ground level than traditional crops, promoting greater soil cover and photosynthetic activity. In conclusion, it is unequivocally clear that agroforests provide a significantly wider range of environmental benefits, such as carbon storage, soil flora and fauna support, enhanced nutrient cycling in the ecosystem, and a better local ambiance than monoculture areas.

Introduction

Modern agriculture is looking for production processes that meet the economic demands from society and are aligned with global agendas for mitigating climate change. In this sense, cultivation methods that have a smaller environmental footprint on ecosystems and act as carbon sinks are considered to be one of the great weapons for achieving the goals of reducing greenhouse gas emissions.

At first glance, agroforestry systems (Portuguese acronym, SAF) appear to be an alternative that meets all these demands. However, to date there have been few studies that integrate different methods of analysis in the same area, allowing for an in-depth scientific view of the environmental benefits of these agro-ecosystems, and thus being able to compare them with large-scale farming methods that are widespread in Brazil.

The aim of this study was to quantify the environmental services provided by agroforestry and compare them with traditional monoculture areas using the integration of a set of soil and vegetation analysis methods in areas in the Zona da Mata and Sertão regions of the state of Pernambuco, Brazil.

Methodology

The study was carried out between June 2022 and February 2023 in 12 study sites. The sites were subdivided by rainfall gradient, with 4 in the Zona da Mata, 4 in the Agreste and 4 in the Sertão. It should be noted that in Pernambuco the longitude promotes significant differences in terms of average rainfall of over 1500 mm/year in the Zona da Mata, while in the Sertão the average rainfall is 580 mm/year. The Agreste region is a transition zone between the two regions (850 mm/year).

Each site was made up of two sample plots, one of which was an agroforestry plot and the other as close as possible to a traditional monocrop (corn, beans, sugar cane or pasture) (Image 1). The proximity was marked by being far enough apart so that there was no influence of management practices between them and close enough so that there were no major differences in rainfall and average temperature between the areas. A total of 24 plots were evaluated in two visits (dry and rainy seasons), totaling 48 samples.

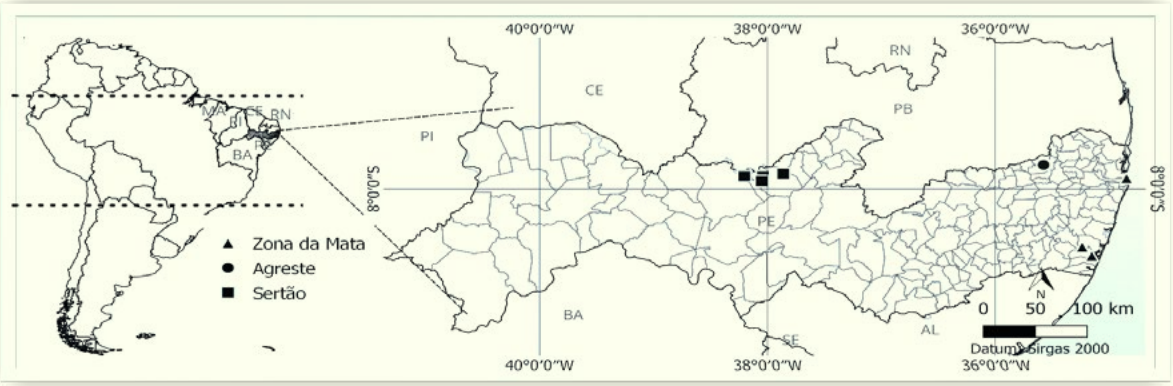

Image 1. Geographical distribution of the experimental sites

In the field, a drone was first flown over the area at a height of 30 meters above the ground, to which a high-resolution RGB camera was attached in order to collect high-resolution images (4K). The team then entered the area and carried out a floristic survey, sampling the biomass of the herbaceous and shrub stratum, allometric measurements that were used to estimate the biomass of trees. Soil samples were then collected in a total of five at the vertices and one in the center of the plot to a depth of 40 cm, to quantify soil density and carbon content using the protocol described by Marcelino et al. (2022).

The biomass and soils collected were processed in the laboratory and analyzed in a CNHS elemental analyzer to quantify the carbon stock, and the data was extrapolated to hectare, following the recommendations of Texeira et al.

The drone images were processed by splitting the sample surface, then subdivided by spectral bands R (Red), G (Green) and B (Blue). The bands were used to generate the Green Leaf Index and the average temperature at ground height using the method described by Fonseca (2022).

Soil gas emissions followed the methodology described by Penha Simon et al., (2019) and enzyme activity for ß-glucosidase (A) and Aryl-sulfatase followed the method described by Prestes & Vincenci (2019).

The data was processed in such a way as to present the average values by region and land use for biomass and soil gas emissions; and spectral data between forest and caatinga and enzymatic activity by type of use.

Results and Discussion

The carbon stocks of the different components evaluated are shown in Table 1.

Table 1. Carbon stocks in biomass, soil and total of agroforestry and conventional monoculture areas in the Atlantic forest, Agreste and sertão of Pernambuco.

Region	Land use	Carbon in bio-mass	Carbon in soil	Total carbon stock (Biomass + Soil)
		---------- (t C) ----------		
Atlantic forest	Agroforestry	43,73	157,03	200,76
	Conventional	5,15	205,76	210,91
Agreste	Agroforestry	19,20	115,12	134,32
	Conventional	6,50	100,18	106,68
Sertão	Agroforestry	21,23	65,33	86,56
	Conventional	3,20	56,67	59,87

Biomass carbon in all land uses showed that agroforests accumulated an average of 8 times more carbon than conventional systems. These results reinforce the role of agroforests as an important tool for carbon sequestration and thus mitigating climate change.

However, this proportion of carbon in biomass and soil is lower in agroforests, where these values represent 3 to 5 times more than the proportion of carbon in biomass, while in monocultures this value can reach 10 times. This much higher proportion in monocultures reveals that the soil carbon values in this type of land use may still be remnants of the storage that occurred in past times with native vegetation cover (forest), which shows a tendency for the values observed today to decline over the years. However, when this proportion is higher in the biomass, it indicates that the above-ground system is still providing organic matter for the soil and that it will continue to increase its carbon over the years.

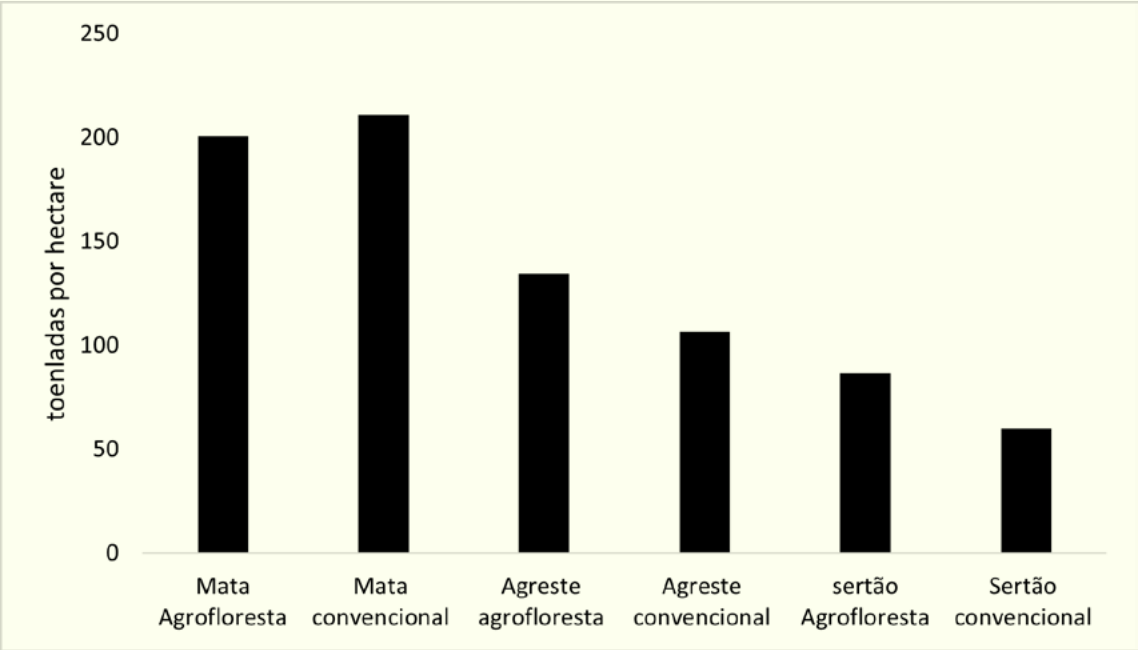

Image 2. Total carbon stored in agroforestry areas and conventional monocultures in three regions of the state of Pernambuco.

Another factor observed is that most of the agroforests visited for this study in the Zona da Mata are currently under little or no management, which hinders nutrient cycling in the areas. The biggest problems observed are: 1) lack of pruning of tree species, shading the area excessively and preventing light from reaching shrubs and herbaceous plants. 2) Loss of biodiversity, a lower number of species than is usually seen in agroforestry in this region. 3) Overgrazing by chickens/other birds. Grazing by animals is a common practice and, if well managed, positive for the regeneration of vegetation, but in excess it can be detrimental to soil life.

The superior carbon stock of agroforestry in the other regions reinforce the importance of this agroecological practice as an important carbon sink. The values observed are very close to those found in native forests (Menezes et al., 2021). The data also reinforces the importance of water availability as a determining factor for the rate of generation of photoassimilates and decomposition of organic matter. Atlantic forest crops store 2.5 times more carbon than semi-arid areas.

Enzymatic activity has been used as an indicator of soil quality activity, which is a function of the past management of the area and how it will behave in the future, as microorganisms are responsible for numerous carbon stock processes and functions, such as the decomposition and cycling of nutrients, synthesis of humic substances, and aggregation of soil particles.

Image 3 shows that microbial activity expressed throughß-glucosidase (A) and Aryl-sulfatase (B) was twice as intense in agroforests as in monocultures. ß-glucosidase, which is a soil enzyme directly related to the carbon cycle, and the bioavailability of organic matter to decomposing microorganisms indicates that these agroecosystems continue to store carbon at a positive rate. Aryl-sulfatase, which is used as an indicator of soil contamination by heavy metals, bioavailability of organic matter and pH balance capacity were twice as high in agroforestry. Our data reinforces that agroforestry soils have greater enzymatic stability and are therefore less vulnerable to anthropogenic/climate actions in a short and medium-term scenario (RAO et al., 2008).

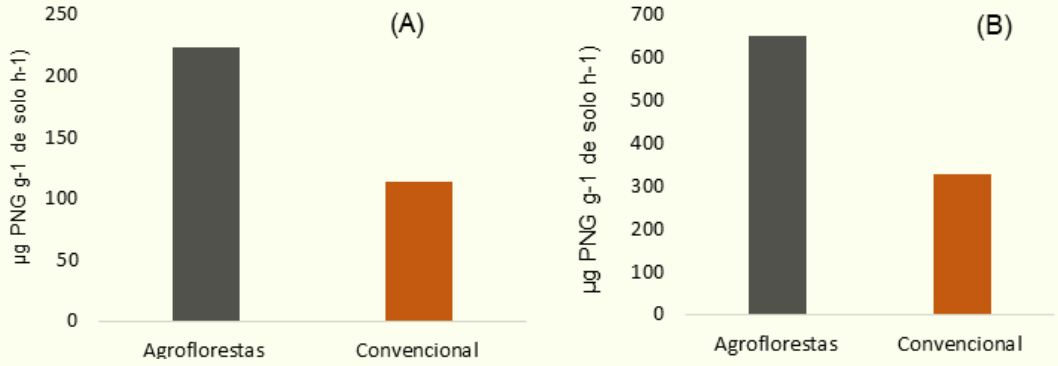

Image 3. Enzyme activity for ß-glucosidase (A) and Aryl-sulfatase (B) in agroforestry and conventional monoculture areas in the state of Pernambuco.

Greenhouse gas emissions from the soil are shown in Image 4. In general, emissions in traditional monoculture areas were higher than greenhouse gas emissions in agroforestry. According to Penha Simon et al. (2019), conventional cultivation systems directly affect greenhouse gas emissions due to environmental conditions, mainly because they use pesticides to eliminate weeds, pests and crop diseases, in addition to using strong soil mechanization, not promoting fallow and soil cover. Repeating a continuous cycle of pesticides, chemical fertilization and harvesting, things that affect the microbial life of the soil (Trovato and Scorza, 2019).

An interesting fact is that, in agroforestry in the Atlantic forest, the methane flux rate was negative, i.e. soil microorganisms were able to remove methane from the air and fix it in forms that do not contribute to global warming. This is not common in anthropized areas, which implies that agroforestry behaves in terms of soil cover like a forest formation. The difference between monocultures and agroforests is more pronounced in the Atlantic Rainforest than in areas of the Caatinga. This phenomenon is due to the lack of water available in the soil during part of the year in this region - during the drought in the Sertão and Agreste, microbial activity is severely limited and, depending on its intensity, ceases.

A higher soil temperature was observed in monocultures (Table 2). Warmer soil temperatures promote an ideal microclimate for soil life, benefiting carbon fixation, as well as promoting the bioavailability of nutrients, which is beneficial for plant development

Table 2. Ground level temperature (°C), ground cover index and Green Leaf Index (GLI) in agroforestry and monoculture areas in the state of Pernambuco.

	Atlantic Forest		Caatinga	
	Agroforestry	Traditional	Agroforestry	Traditional
Temperature at ground level (°C)	25,1	30,5	24,5	32,4
Ground cover index	0,95	0,32	0,76	0,18
Green Leaf Index (GLI)	0,88	0,56	0,72	0,21

The monocultures also showed lower soil cover and photosynthetic rate, which makes them more susceptible to the effects of climate change (Table 2).

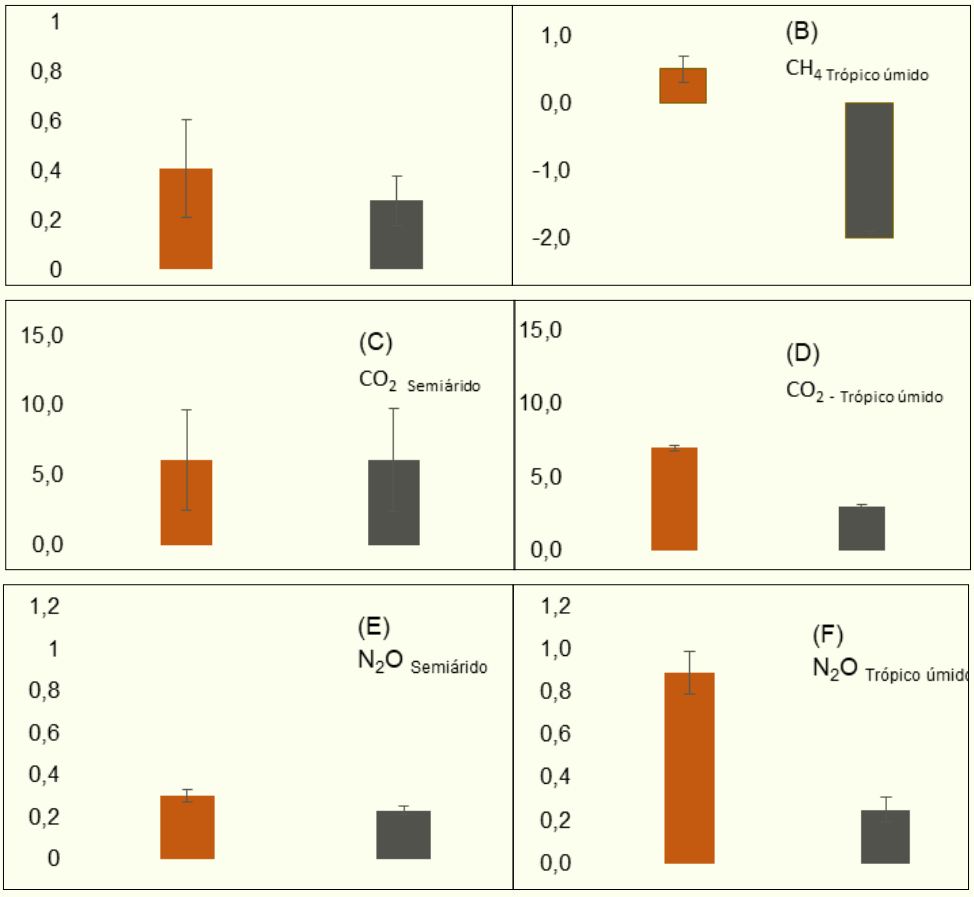

Image 4. Greenhouse gas emissions from agroforestry soil (green bars) and traditional crops (red bars) in two biomes in the state of Pernambuco. Methane CH4 = A Semiarid, B Zona da Mata; Carbon dioxide CO2 = C Semiarid, D Zona da Mata and nitrous oxide N_2O = E Semiarid, F Zona da Mata.

The bars represent the standard deviation from the mean.

Image 5 provides a didactic illustration of how photosynthetic activity behaves in monocultures, pastures and agroforests. Agroforests visibly have a higher vegetation index, which is an indicator of photosynthetic activity by plants, and it should be noted that this is the process by which plants fix carbon.

Likewise, the GRI is an indicator of the land cover index and heat spots. Once again, monocultures have proven to be an agricultural activity that is not very conservative in terms of soil management practices.

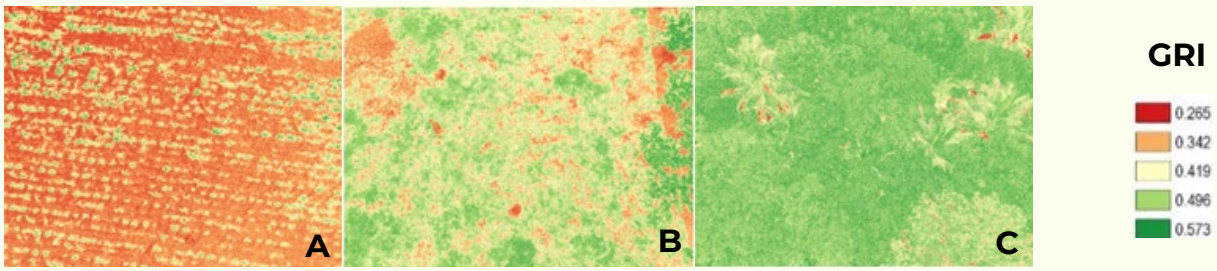

Image 5. Photosynthetic activity indicator. (A) Maize monoculture, (B) Cultivated pasture (C) Agroforestry.

Crops with a higher proportion of bare soil are more susceptible to erosion and therefore soil loss. In addition, bare soil has a higher temperature, which indicates that these systems are less efficient in terms of water use.

In terms of species diversity, comparing monocultures and agroforests is something we consider to be unnecessary, given the very name of these systems. What we decided to look at in this study was the diversity between agroforests in the three study regions (Image 6).

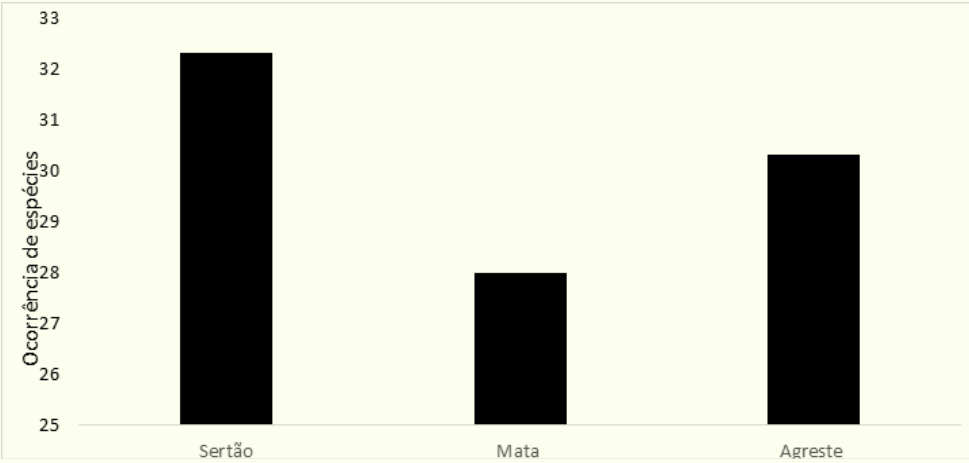

Image 6. Biodiversity of plant species observed in agroforests in three regions of the state of Pernambuco (Sertão, Zona da Mata and Agreste).

One of the great strengths of the agroforestry concept is that biodiversity makes crops more resilient than when they are grown in isolation. Numerous studies have proven that polycultures are beneficial for pest and disease control, re-

duce greenhouse gas emissions and improve the food sovereignty of rural families. Surprisingly, in our study we found that agroforestry in the (drier) Sertão region is more diverse than agroforestry in the Zona da Mata. These results reinforce the need to expand agroforestry studies and revive the importance of agroforestry management practices in these areas. Less plant diversity can occur due to the overgrowth of tree canopies preventing light from reaching smaller species.

Conclusões

Based on the set of scientific methods used in this study, agroforests store more carbon in the vegetation, improve beneficial microbial activity in the soil, reduce greenhouse gas emissions from the soil, carry out more photosynthesis and promote a more life-enhancing microclimate than traditional monoculture areas.

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