Morada Ekoa: Cultivating Connection

A case study analysing the economic, social and ecological values of Morada Ekoa complemented by consultation to guide future resilience.

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Abstract

While humanity is at risk to cross thresholds that will cause non-linear, abrupt environmental change on a planetary scale, an epochal transition known as the '*Great Turning'* is taking place as we shift from an industrial growth society to a life-sustaining civilization. This shift is embodied in permaculture communities, which serve as leaders of change by demonstrating regenerative ways of living. This is a case-study conducted at permaculture institute 'Morada Ekoa', situated in the municipality of Imbituba, Santa Catarina, Brasil, with three main goals:

1) Describe the vision of Morada Ekoa and resulting practices to achieve this vision.
2) Analyse the economic, social and ecological values generated by Morada Ekoa.
3) Provide consultation on all the facets of Morada Ekoa to support its continued growth and resilience.

Morada Ekoa has transformed the land from monocultural cropland to a thriving permaculture institute, according to its central ethics *earthcare*, *peoplecare* and *fair share*. By creating conditions conducive to life, nature is empowered to create abundance and give back boundless benefits, referred to as ecosystem services.

Morada Ekoa generates economic, social and ecological value. Economic value is created though three primary streams: 50% ecotourism, 25% education and 25% food production. Social capital is cultivated as Morada Ekoa serves as an example and shows alternative ways of living; the reconnection of people and planet in a permaculture community creates a sense of belonging, improves cooperation, and ultimately well-being. Ecological value is enhanced by (1) accelerating natural soil-building processes to create a healthy functioning soil system capable of supporting a biodiverse agroecosystem, and (2) planting a wide variety of plants species. This increases habitat complexity and niche availability, thereby resulting in a biodiverse and redundant agroecosystem.

Executive summary

The study conducted at Morada Ekoa had three main objectives:

1) Describe the vision of Morada Ekoa and resulting practices to achieve this vision.
2) Analyse the economic, social and ecological values generated by Morada Ekoa.
3) Provide consultation on all the facets of Morada Ekoa to support its continued growth and resilience.

Morada Ekoa is guided by the central permaculture ethics *earthcare*, *peoplecare* and *fair share*. It uses permaculture principles and techniques, to create a thriving agroforest and pleasant home environement. By creating conditions conducive to life, nature is empowered to create abundance and give back boundless benefits, referred to as ecosystem services.

Economic value is created though three primary streams: 50% ecotourism, 25% education and 25% food production. In 2 months, April and May 2024, a total of 258 kg of food has been harvested from the land, with a value of approximately $R2000.

Social capital is cultivated as Morada Ekoa serves as an example and shows alternative ways of living; the reconnection of people and planet in a permaculture community creates a sense of belonging, improves cooperation, and ultimately well-being.

Ecological value is enhanced by (1) accelerating natural soil-building processes to create a healthy functioning soil system capable of supporting a biodiverse agroecosystem, and (2) planting a wide variety of plants species. This increases habitat complexity and niche availability, thereby resulting in a biodiverse and redundant agroecosystem.

The most important advice is presented in the form of actionable items:

- To produce food surplus, plant more agroforest, there is plenty of space.
- To be more self-sufficient, plant more staple foods, such as mandioca (cassava).
- To efficiently earn money from food production, focus on cash crops (high $R/kg).
- To achieve ambitious goals, such as opening a café, seek partnerships.
- To secure a sponsor and attract sufficient participants for courses, or to draft a grant proposal for a school project, begin early and plan meticulously; dedicate specific times each week to accomplish defined tasks.
- To ensure habitat for nature and minimise management efforts, keep tight management on exotic species, take it out root and all once they no longer serve their purpose.
- To improve biodiversity, provide nesting locations for birds, bats and insects.
- To use the landscape to your advantage, plant on top of the hill where organic matter has already improved soil quality.
- To improve the functioning of the soil system, keep providing abundant organic matter to developing systems
- To provide a kickstart of microbial diversity to a developing soil system, add one bucket of leaf litter and one bucket of top soil from a healthy soil system per newly planted line.
- To make sure your system has sufficient amounts of nutrients, take possible N-immobilisation into account when supplying high C/N organic matter to fast-growing annual crops.
- To improve the functioning of the soil system, try out biochar as soil amendment to improve soil organic matter

Acknowledgements

First of all, I would like to thank Morada Ekoa and its most hospitable inhabitants, for allowing me to stay, learn and contribute. Thank you Felipe, Jana, Nalu and Noah, Isac, Leo, Fernanda, Marie and Lucas. I had an amazing time, learned a great deal, personally and professionally, and you earned a place in my heart.

Specifically, big thanks to Felipe for the many lessons on tropical agroforestry and bioconstruction, for the fun and dreamy talks about the future and the many hours spent together in the ocean.

Next to that, I would like to thank Jaco Appelman for his guidance in supervising this internship project. It wasn't always easy, but I could always count on your creative support, always finding different angles or ways for me to approach certain problems.

Last, but not least, I would like to thank Lisa Kluis, for her perpetual support in my project. Her optimistic encouragement helped me combat through times of existential crisis and self-doubt, a common phenomenon affecting students working on their thesis. She was a perfect partner offering in-depth discussions, which helped me to further explore certain ideas.

Altogether, this minor research project was an amazing experience that has definitely shaped and moulded my ideas of a perfect future. I will take the personal, academic and professional lessons that I learned with me for the rest of my life, and am very grateful for the opportunity given to me.

AI statement

ChatGPT, a type of generative artificial intelligence, was used in the formation of this study report for certain, specific tasks. While creating graphs and tables using the program R studio, I made use of ChatGPT whenever I encountered a problem I could not solve easily. Next to that, I used ChatGPT to sum up key concepts of certain theories and find simplified definitions, which helped me interpret and express these in the text.

Contents

Introduction

The prevalent western definition of 'nature' – the whole of material reality, considered as independent of human activity and history – places a great divide between nature and culture (Ducarme & Couvet, 2020). This 'great divide' between nature and culture is a fundamental cause of the environmental predicament the world is currently facing (Lent, 2021).

"The Anthropocene is the epoch in which the activities of a single species, us *Homo sapiens,* have altered global geophysical processes, threatening the resilience of the Earth System and its own very existence (Steffen et al., 2011). The safe operating space to keep the Earth System in its stable, accommodating environment of the Holocene has been determined using nine planetary boundaries (Rockström et al., 2009). Currently we have transgressed the safe operating space for six of the nine planetary boundaries, thereby risking to cross thresholds that will cause non-linear, abrupt environmental change on a planetary scale. The planetary boundaries at risk are: novel entities (environmental pollutants, including plastics), loss of biodiversity, biochemical flows (N&P loading), green freshwater change (water availability for plants), land-system change (deforestation), and climate change (Persson et al., 2022; Steffen et al., 2015; Wang-Erlandsson et al., 2022). To keep the Earth System in a stable state, a system change is necessary." (Koebrugge, 2023, p. 7)

Humans are an integral part of nature, we depend on the natural world for our survival and cannot place ourselves outside of nature. Not only do we depend on a healthy ecosystem to provide us with services such as clean air, clean water, or food, a connection to the natural world is also highly important for human health, productivity, and wellbeing (van den Bosch & Ode Sang, 2017). To ensure a viable continuation of human life on the planet earth we must bring nature and culture back together.

Agroecology is a field that does so by employing natural processes in agriculture. Agroforestry, a form of agroecology, is defined as:

> *"a dynamic, ecologically based, natural resource management system that diversifies and sustains production in order to increase social, economic and environmental benefits for land users at all scales"* (FAO, 2022).

Agroforestry follows life principles, as it uses biological processes to grow food, fertilize, control pests and diseases. By doing so, the system mimics aspects of a 'natural' ecosystem. It has been found that agroecological management increases plant diversity, which in turn has a positive effect on soil quality, while crop yields remain similar or increase, compared to conventional farming (Teixeira et al., 2021).

Nowadays there is a lot of talk about sustainability, but to 'turn this sinking ship' we need more than that, we need regeneration. Sustainability, from the Latin 'sustinere', means to uphold or maintain, however, just maintaining society as it is now, will not be enough. To halt the reinforcing, positive feedbacks loops that are accelerating climate change, such as the interaction between warmer temperatures and ice melt, we need to not only sustain, but make a positive impact. As put by Reed, in his theory on whole systems design:

> "instead of doing *less damage* to the environment, it is necessary to learn how one can *participate with* the environment by using the health of ecological systems as basis for design" (Reed, 2007).

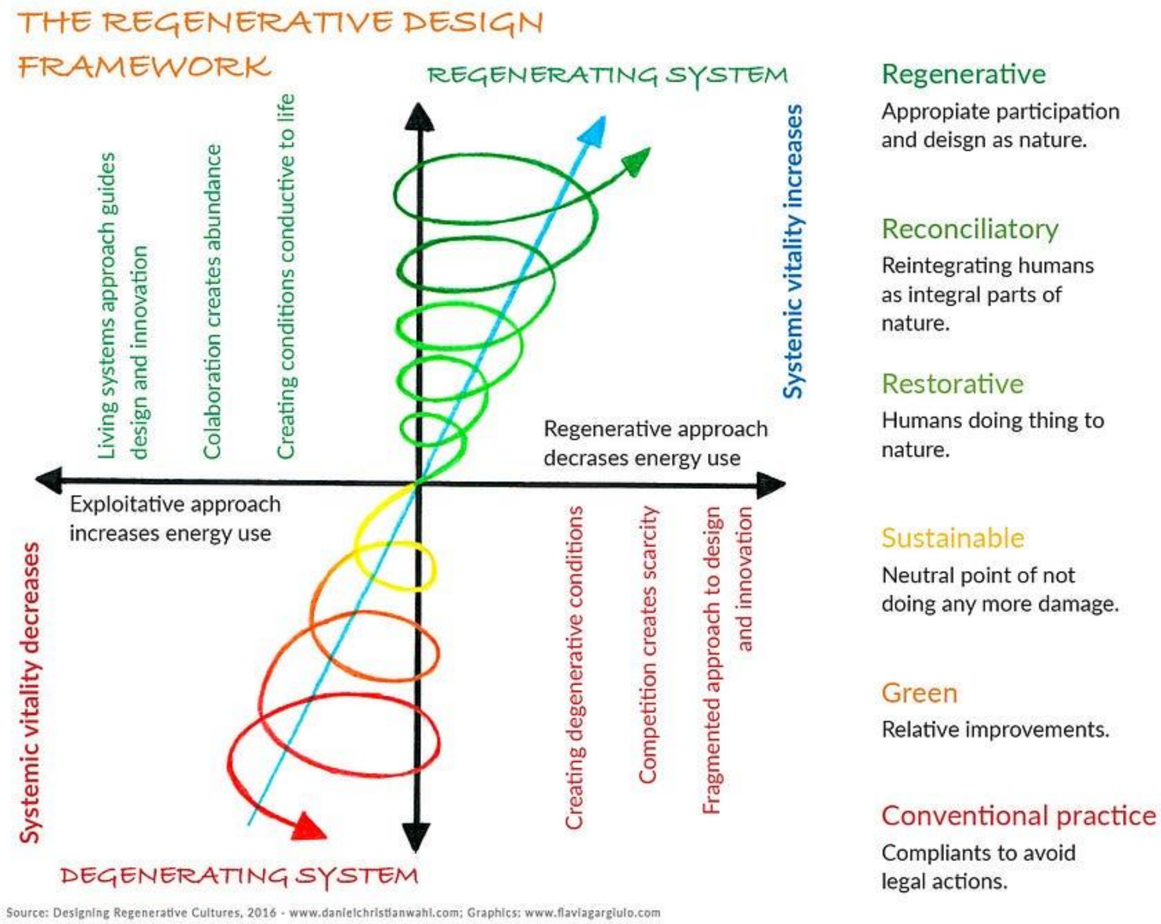

Figure 1 Regenerative design framework, adapted from Reed (2007)

The foundation of our much needed system change has been laid in whole or living systems thinking. *Whole systems thinking* recognizes that the everything is interconnected, and moves us beyond mechanics into a world activated by complex interrelationships – natural systems, human social systems, and the conscious forces behind their actions (Reed, 2007). The most important properties of systems thinking are, as articulated in the systems view of life (Capra & Luisi, 2014):

- **Interconnectedness**: Recognizing that all components of a system are interconnected and that changes in one part affect the whole.
- **Emergent Properties**: Understanding that the system's overall behavior and properties emerge from the interactions of its parts, making it more than just the sum of its parts.
- **Feedback Loops**: Identifying the presence of feedback loops, which help to stabilize or destabilize a system by amplifying or dampening changes.
- **Self-Organization**: Observing that systems have the capacity to self-organize, evolving in complexity and adapting to changes dynamically.
- **Holism**: Viewing systems as holons, meaning each system is a whole in itself but also a part of larger systems, emphasizing the nested nature of systems within systems.

The much needed, radical systems change, similar in scale to the agricultural or industrial revolution many years ago, is under way as we are shifting from an industrial growth society to a life-sustaining civilization. This epochal transition is known as the '*Great Turning'.* Applying systems thinking to the Great Turning creates a story of hope.

First of all, when many people come together to participate in the Great Turning, emergent properties will arise, creating collective strengths and new possibilities that exceed individual efforts. Self-regulating feedback loops will stabilize our earth system, for instance resource depletion is now driving demand for alternatives. As regenerative communities grow, the systems, tools, and skills they can employ for earth- and people care will evolve and grow in complexity. And lastly, by acknowledging that we are deeply embedded within and dependent on broader ecological systems, our positive actions will ripple across other systems.

The Great Turning is embodied in permaculture communities, which serve as leaders of change by demonstrating regenerative ways of living, clearly manifested in their building and agriculture practices. They serve to inspire broader societal shifts towards ecological stewardship and social equity. There are valuable lessons to be learned from the years of practical experience these communities have in restoring the relationships between nature and culture.

In this minor research project, I intend to gain more insight in the principles and practical application of bioconstruction and agroforestry, as practiced at a permaculture institute called 'Morada Ekoa'. Next to that, I would like to support the goals of Morada Ekoa and leave behind some contributions, both practical and conceptional. Therefore this minor research project will explore the following question:

How can we improve the functioning of Morada Ekoa for all its participants, including nature, to ensure future resilience?

This research question will be examined using the following sub-questions.

1) What is the vision of Morada Ekoa and what practices are employed to achieve this vision.
2) What are the economic, social and ecological values generated by Morada Ekoa.
3) What consult can I provide on all the facets of Morada Ekoa to support its continued growth and resilience.

Morada Ekoa

In Brazil there are many ‘eco-lodges’, however, most of them do not do justice to the word ecological, but just commercially exploit the term ‘eco’. Morada Ekoa is a station of sustainability and permaculture, an eco-retreat that actually uses ecological practices. Ekoa is the indigenous Guarani Mbyá word for home, exactly the objective that Morada Ekoa is trying to achieve: a *home* for all inhabitants. Morada Ekoa aims to restore the relationship between land and people. If people love the land and feel like the land loves the back, they would not harm it. Put beautifully by Robin Wall Kimmerer: “A garden is a nursery for nurturing connection, the soil for cultivation of practical reverence. Once you develop a relationship with a little patch of earth, it becomes a seed itself (Kimmerer, 2013)*”*. The bioconstruction and agroforestry practices conducted and taught at Morada Ekoa bring people back in contact with nature. This connection is good for the health of the earth and the health of the people and, once reestablished, this connection will be taken home and continue its spread. The Morada Ekoa station seeks to serve as an example for interested individuals or institutions in practicing permaculture. Courses on bioconstruction, waste water management and agroforestry are organised to share the knowledge about permaculture. They have created a harmonious environment, that integrates tourism, spare time and food production with nature conservation and a healthy environment.

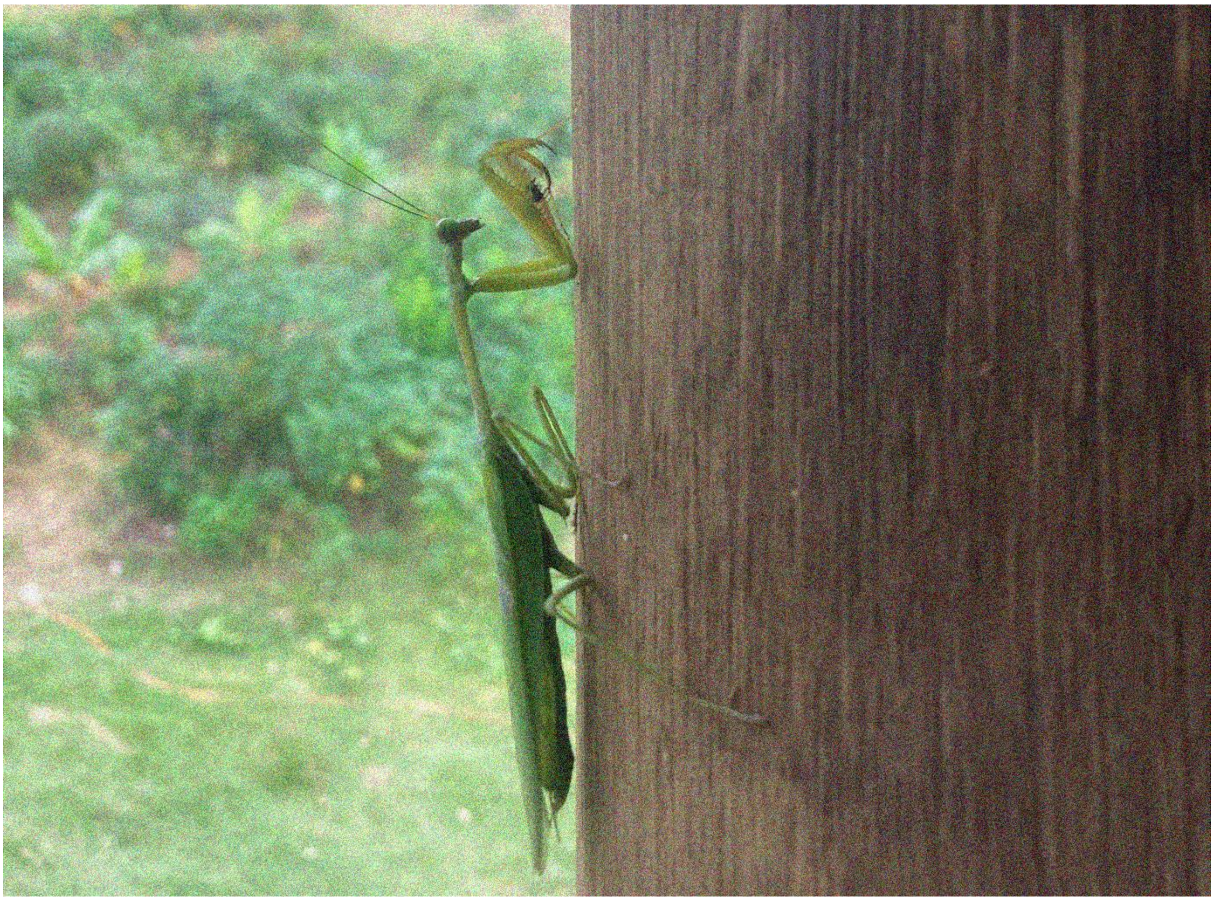

Figure 2 Praying mantis, picture taken by author

Location

Morada Ekoa is located in the municipality of Imbituba, Santa Catarina, Brazil (see figure 1). It is situated in a coastal area, only 3 km from *Praia da Barra de Ibiraquera* and the Atlantic Ocean. The coastal area is characterized by large mobile sand dune systems always being moved around by the wind, the nearest is known as *Areais da Ribanceira*. There is a freshwater lake, *Laguna doce,* 500 meters southeast of Morada Ekoa, and a big brackish lagoon, *Lagoa da Ibiraquera,* 800 meters to the north, that, at times, is connected to the Ocean.

The highway, BR 101, runs 2 km west of Morada Ekoa. West of the highway are big stretches of rice plantations around Rio D’Una. Rio D'Una is born further west in the Serra do Tabuleiro, a protected, mountainous forest, and ends in Lagoa do Mirim, southwest of Imbituba. The whole region is part of the catchment area of Rio D’Una, which is the water source of both Imbituba and Garopaba, and all of the wetland systems and lakes.

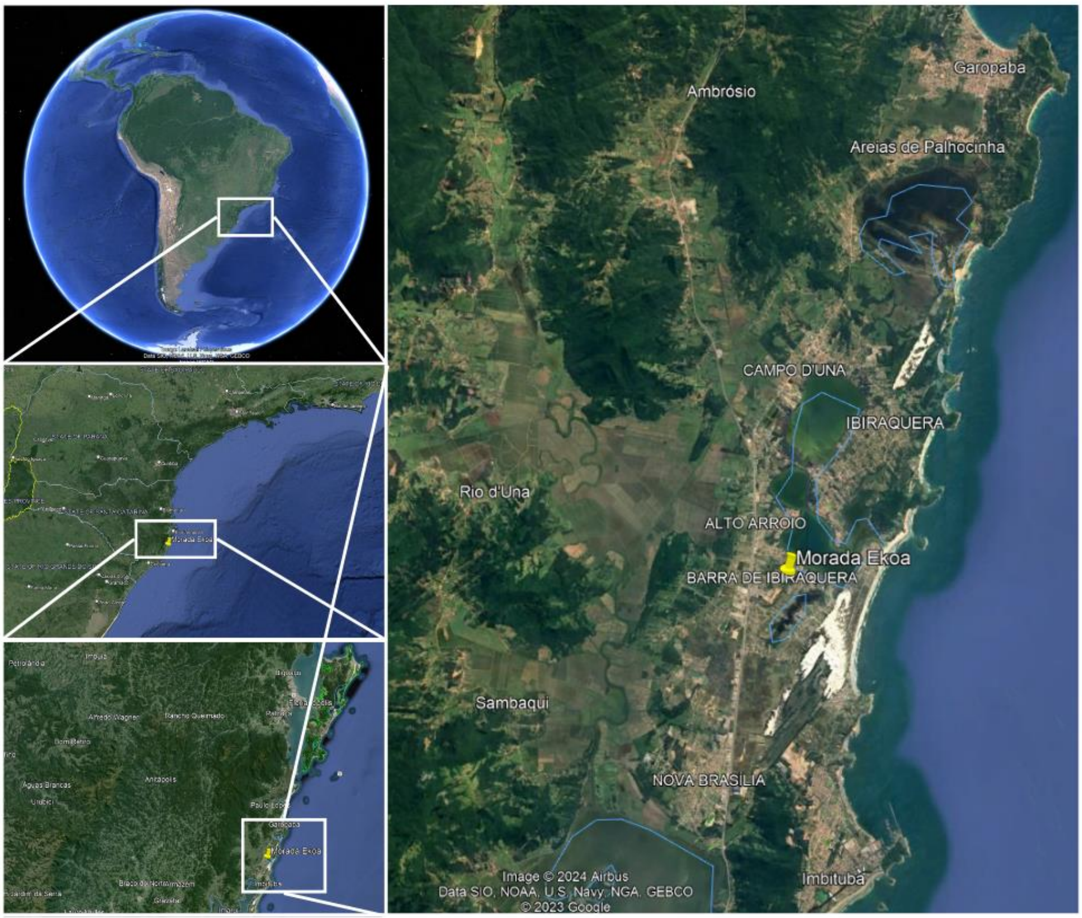

Figure 3 Location of Morada Ekoa

The land cover of the area around Lagoa da Ibiraquera has changed substantially from the original vegetation. The change in land use and cover around Lagoa da Ibiraquera from 1880 to 2008 has been subject to study (Rodrigues De Freitas et al., 2012). According to the most recent survey of 2008, 42,4% of the land still has its original vegetation land cover (17.2% restinga, 14.9% Floresta Ombrófila Densa, 10.3% beach and dunes). More than half the land has changed entirely, with the land cover now made up of; 18.2% urbanisation, 17% pastures, 10% capoeirinha (natural regrowth in pastures) and 8% agriculture. In recent years, the tourism industry of Garopaba and Imbituba has grown, resulting in more urban development.

The main industries of the area used to be agriculture, primarily pastures and production of mandioca, and fishing (Hoffman de Oliveira, 2008). The main economic driver of the area has now shifted towards tourism, making construction on of the main industries. The municipality of Imbituba has 52.581 inhabitants, with a density of 290 per km^2(Governo, 2024). According to data from 2010, only 61% of homes in Imbituba have an adequate sanitation system, posing serious threats to the water quality of lagoons and groundwater. There are some waste sorting facilities where recyclables are separated, but most of the domestic waste ends up in a landfill.

Figure 4 Left: Native Restinga vegetation, with Arroio, lagune and serra in the background. Right: Areais da Ribanceira, with Atlantic Ocean in the background

Weather and Climate

According to the Köppen-Geiger classification system the climate is humid subtropical, characterized by year-round high humidity, around 80%, and average temperatures between 15 ℃ in winter and 27 ℃ in summer (World Weather Online, 2024). Average yearly precipitation is 1748.5 mm, with an average of 103 rainy days a year. The summer months generally have a bit more rain than the winter months.

History

Before the arrival of European colonizers, the entire east coast of Brasil was covered by the *Mata Atlantica* (Atlantic forest), a biodiversity hotspot with a higher plant species diversity than most of the Amazon forests (Joly et al., 2014). Currently, less than 16% of the Atlantic forest remains, of which most is made up of small forest fragments surrounded by open human-modified landscapes, resulting in widespread edge effects (Ribeiro et al., 2009). In just five centuries most of the Atlantic forest has been exploited and degraded, first by the exploitation of agricultural commodities, followed by urbanisation, currently 70% of Brazilians live in Atlantic forest domain, and Eucalyptus plantations (Pizo & Tonetti, 2020).

The Imbituba region was first visited by missionaries from Rio de Janeiro in 1622 who came to describe and categorize the indigenous people that lived along the coast (Hoffman de Oliveira, 2008). The native people that once lived along the coast belonged to the Guarani linguistic groups (Cruz et al., 2020). They have long influenced forest composition and species distribution in the 'pristine' forests of this region. In 1715 fishermen and farmers moved from Laguna, in the south, looking for new agricultural and whaling grounds (Hoffman de Oliveira, 2008). In 1870 the first pier of the Imbituba port was built and from 1922 the development increased as more ships were making port.

The soils of the area are made up of quartzite sands, that are quite acidic, low in nutrients and have a high water permeability. The original vegetation in this coastal area consisted of Dense Ombrophilous Forest, that grew around the lagoons and in depressions below 30 meters elevation (Freitas & BELTRAME Beltrame, 2013). The sandy hills above 30 meters elevation were occupied by Restinga vegetation, characterised by sparser vegetation, with smaller trees. By 1957 more than half of the original vegetation around lagoa da Ibiraquera had been converted to agriculture (26%) and pastures (29%) (Rodrigues De Freitas et al., 2012).

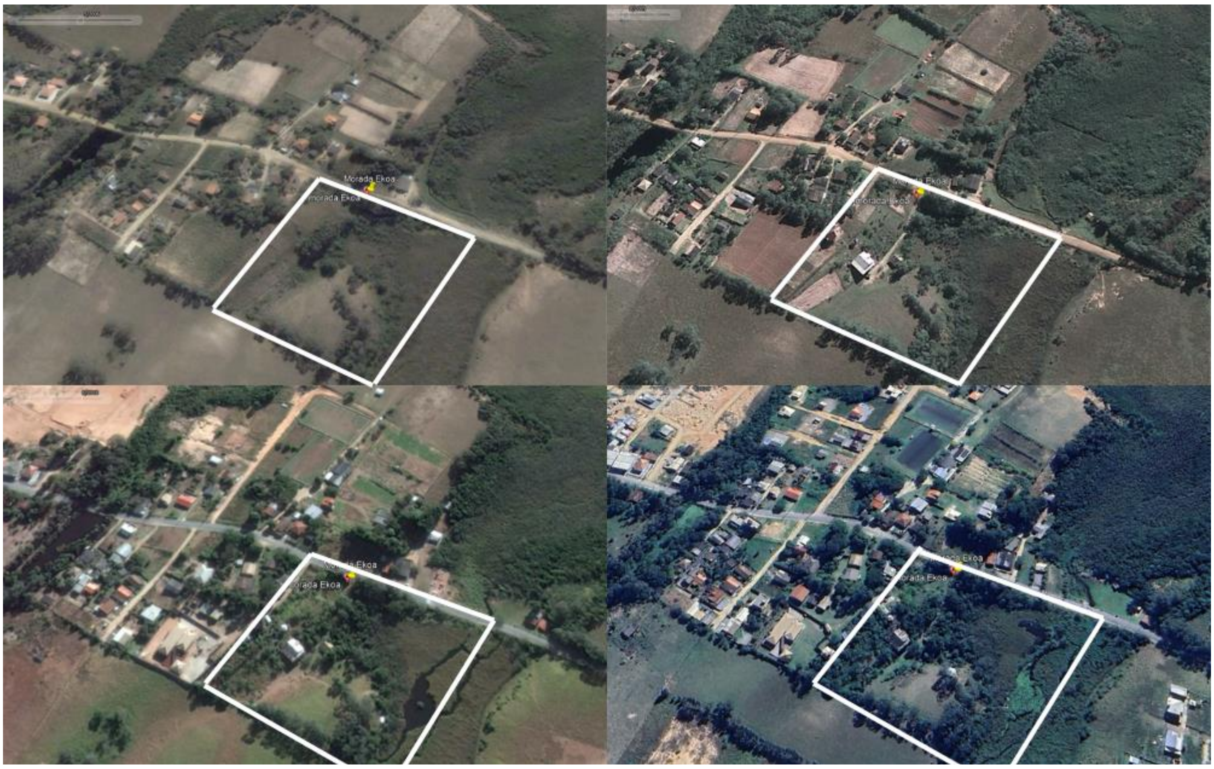

Figure 5 Google earth satelite photos from the years 2006, 2009, 2016, 2023. (from left to right, top to bottom)

The land for the project was bought in 2006 and the main house was finished in 2008, as part of the thesis project of Felipe Hoffman de Oliveira. The whole plot comprises of 2 hectares with some small elevation difference of 10 meters between the lowest and highest point. At the east side of the land is a marshy area with a small river (*Rio Barbosa)* that flows into Lagoa da Ibiraquera. This small swampy area still has some native Dense Ombrophilous forest vegetation. Next to that, there were some native species left on the margins of the land, such as butia, vassoura and guave. Before the land was bought, it was used for the grazing of cattle and the production of mandioca and coffee. The previous owner had planted eucalyptus trees to use for firewood and the production of mandioca flour. Since it has been bought, the land has undergone a transformation from pasture/mandioca plantation to permaculture food forest, as can be seen in figures 3 and 4.

Figure 6 Transformation over the years 2006, 2008, 2018, 2024 (left to right, top to bottom)

For the past 16 years the land of Morada Ekoa has been shaped and transformed according to permaculture and bioconstruction principles in order to minimise the environmental impact while creating a pleasant home environment. The land now has one main house, three small chalets and a family house. These houses have compostable toilets, and waste water is treated locally. Surrounding these houses is a healthy, flourishing permaculture system, that is still being expanded to cover more land. Morada Ekoa seeks to serve as an example to schools and interested individuals, and therefore organises courses on bioconstruction and permaculture to share their knowledge. The bioconstruction, waste water and permaculture practices will be discussed in the coming chapters.

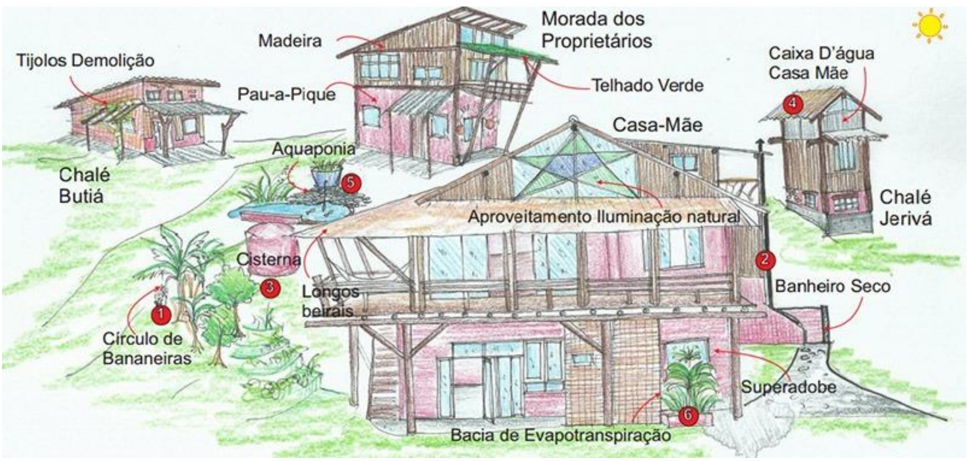

Figure 7 Bioconstructed buildings of Morada Ekoa, drawing by Gabriella

Bioconstruction practices

Currently, the construction industry uses almost exclusively reinforced concrete, steel and other industrialised materials. To put it into perspective, concrete is the second most-produced and consumed substance on Earth, second only to water (Arıoğlu Akan et al., 2017). The production, transportation and assembly of these materials is very energy intensive, emits a lot of greenhouse gasses and therefore has a big impact on climate change and global warming. Cement production alone, a critical input to concrete, accounts for approximately 5% of all CO_2 generated by human activities worldwide (Benhelal et al., 2021; Rodrigues & Joekes, 2011). To effectively mitigate anthropogenic impacts on Earth's ecosystems and adhere to our climate targets, the construction industry must change to reduce its environmental footprint.

Bioconstruction is a building technique that uses local, natural building materials in a sustainable way, to create a building more integrated with its surroundings (Hoffman de Oliveira, 2008; IPEC, 2024). Bioconstruction is not at all a new concept, before industrialized building materials, all structures were made by hand from earth, stone and wood. One ancient technique that has recently been revived as sustainable building method is adobe. Adobe is a paste made from a mixture of clay, sand, straw, cow poo and water, that can be shaped into a brick and dried in the sun. Adobe bricks were used widely throughout the ancient world, from the pyramids in North Africa, Arg-é Bam in the Middle East, to whole cities in the Andes. The earliest adobe brick structures were found in northern Peru and dated to 5100 years before present date (Mauricio et al., 2021).

Figure 8 Casa Mae, a high standard, durable home, built using superAdobe sandbags.

To build a high standard, comfortable and durable home, it is not necessary to use industrial materials such as concrete and steel. Natural materials, sourced locally, can provide the same level of quality, while minimising environmental impacts (see appendix V). Bioconstruction offers the following benefits:

- **Sustainable**: Adobe bioconstruction utilises natural materials such as clay, straw, wood, and even recycled materials like old wood, tires and glass bottles. These materials are renewable, abundant, and have minimal environmental impact compared to industrial materials like concrete and steel. Moreover, when a building is at the end of its live, it can be demolished and reused as functional soil in the garden.
- **Energy Efficient**: Natural materials have excellent thermal properties, providing effective insulation and reducing the need for heating and cooling. This leads to lower energy consumption and costs over the lifespan of the building.
- **Healthy Indoor Environment**: An adobe wall is alive, it breaths air, regulates humidity, absorbs pollutants, thereby promoting good indoor air quality. This can lead to improved comfort and well-being for inhabitants, especially for people with respiratory sensitivities.
- **Cost-effectiveness**: Materials used in adobe and bioconstruction are less expensive and can be sourced locally, substantially lowering building costs.
- **Empowerement:** Bioconstruction enables anyone to build a home, as the materials are cheap and easy to obtain, all that is needed is knowledge, time and motivation.
- **Aesthetic Appeal**: Adobe and bioconstruction techniques offer a wide range of design possibilities, thereby allowing users to be creative and design visually appealing eco-homes.
- **Carbon Sequestration**: Some natural materials, such as straw and wood, have the potential to sequester carbon dioxide from the atmosphere, by using these materials in construction this carbon is stored in the building. Therefore a bioconstruction house has the potential to be CO_2-negative, taking more CO_2 from the air than its building processes generate.

There are a number of different adobe building techniques, each with its own advantages and considerations, depending on the specific environment, climate and resource availability. The different techniques all rely on the same composition to make a plaster, ideally, 15% clay, 10-30% silt and 55-75% sand (Santos et al., 2020). See ideal soil composition in figure 9, numbers indicate adobe sample composition taken from different sites across the world (Coffman et al., 1990). The clay used cannot be more than half expansive clay, or the plaster/ bricks will crack when dry.

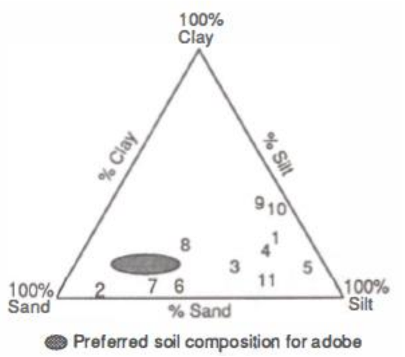

Figure 9 Adobe soil composition, numbers indicate study sites across the world (Coffman et al., 1990)

To test the composition of the locally available soil a simple sedimentation test can be performed. Add soil to a jar, fill about 30-50%, submerge soil completely with water. Shake jar to create homogeneous mixture and place jar somewhere flat to let soil settle overnight. The soil particles will separate based on size, forming different layers. The heaviest particles, sand, will settle first, followed by silt and clay, with the finest particles, on the top. By measuring the thickness of each layer, you can calculate the texture percentages of your soil.

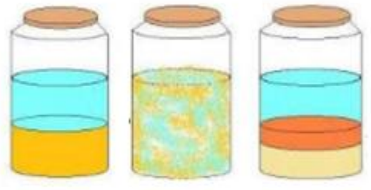

Figure 10 Soil composition test, (1) soil and water (2) mixture (3) 67% clay, 33% sand and water

The process used at Morada Ekoa to prepare the primary plaster, is as follows. Sand and clay, 2:1, some coarse sand, cow poo that has been soaked for one day and straw, cut up in small pieces, are mixed together with water by using the feet. Water is added gradually while the plaster is being mixed, until the plaster has reached its ideal consistency. Consistency of the plaster can be tested, by taking a handful of plaster, rolling it into a cylinder and holding it at one end. If the cylinder maintains its shape, the plaster is ready to use. When the plaster dries, it will shrink about 10%, so it is normal that cracks appear that have be restored with additional layers.

This plaster can be made into adobe bricks by pouring the mixture into moulds. The bricks are then left in the sun to dry, with a small layer of straw over them, so they do not dry to quickly and crack. The dried bricks can be used to build a wall with some wet plaster to bind the bricks together.

The plaster can also be applied directly onto a structural framework of bamboo or woven sticks, a technique called Wattle and Daub (*pau-a-pique*). The benefit of this method is that it offers flexibility in design of, for instance curved or irregular shaped walls, enabling unique, artistic walls. Besides, this method is a bit easier and quicker to work with, as it doesn't require you to first make bricks. However, as the plaster is not so sturdy when making it, it might be impossible to build very high or thick without waiting first waiting for the base to dry.

Next to these techniques there is a slightly different method that uses long bags filled with earth: SuperAdobe. SuperAdobe is a more recently invented method, that gained a lot of attention after publishment by NASA and the United Nations. This technique was selected to build the Morada Ekoa main house (*Casa Mãe*). The walls are thick and structural, omitting the need for beams or pillars, and furthermore, providing excellent insulating properties. Moreover, the sandbags do not require a specific sand/clay mixture, so it can even be used in regions with very sandy soils. The biggest disadvantage is that this method is work intensive and costs a lot of time.

To build the Casa Mãe the cheapest soil materials were chosen and it was tested which mixture yields the best results, coming to a composition of 1 red sand (silty) : 1 clay : 1 coarse sand : 1 gravel (less as wall gets taller), supplemented by 10% cement. Earthbags are filled with a pre-mixed and sieved moist soil and stacked in layers to form walls. The bags are made of polypropylene, 40 cm wide and as long as desired. Natural alternative could be bags made of hemp fiber. Every layer is compacted as the bag is filled and barbed wire is used as both mortar and reinforcement. After completion, the walls are plastered for protection and aesthetic appeal.

After the first, or multiple primary layers of adobe, a secondary layer is applied with a slightly different composition to give additional protection and provide a smooth, clean-cut finish. The secondary plaster consists of the following pre-sieved components: 2 parts clay, 1 part sand, 1 part extra fine sand, 0.5 parts stone flour (from marble stone), and 0.5 kg salt. The Prickly Pear cactus (*Opuntia sp.*) is immersed in water for one day, subsequently, the water is sieved and added until the desired consistency of the plaster is reached. The inclusion of cactus juice renders the plaster more water-resistant, yet still permeable, facilitating breathability of the wall. Salt is incorporated to deter insect damage to the structure.

When the adobe wall is very exposed to the elements, a third layer can be added to prevent water damage. This might be necessary to make the wall more durable. This layer is made by adding PVA wood glue and some Portland cement to the plaster. PVA wood glue is biodegradable under the right conditions of moisture and microorganisms.

After the final layer, the wall can be painted with natural paint, to give a nice finish. White paint is made by mixing lime ($CaCO_3$) with cactus-soaked water. Natural pigments can be added to create different coloured paints. Given the climate of Santa-Catarina, it is necessary to provide ample rain protection. Water is the biggest enemy, as all of the components are soluble in water. Just like a farmer, the house needs sturdy boots and good hat; a strong fundament and big overhanging roof.

Water management

In the municipality of Imbituba the sanitation infrastructure is not adequately developed, only 6.78% of homes have access to a centralised sanitary sewer system (Instituto Água e Saneamento, 2024). Of the remaining homes, 52.6% have some sort of individual solution and a shocking 37.4% of households lack any sewage collection or treatment. Untreated sewage poses serious risks to human health, the community and environment. Water sources can be contaminated by disease, foul odours accumulate and aquatic ecosystems can be harmed by pollutants.

The management of our waste should not be viewed solely as a challenge, but rather as an opportunity: our waste is a valuable resource (Hoffman de Oliveira, 2014). By adopting local ecological sanitation systems to treat wastewater, this potential is harnessed, transforming waste into nutrition for a variety of organisms, ultimately purifying the water and generating food. Through local waste treatment, the burden of waste management shifts from a collective issue to an individual responsibility, fostering a profound awareness of our interconnectedness to the living ecosystem.

At Morada Ekoa rain water from Casa Mãe is collected and stored in a big 10.000L tank. This water could be used for drinking, but is primarily used for watering the garden. Grey water, all the domestic waste water except the toilet, including kitchen sink, washing machine, etcetera, is treated using a banana circle. Water first passes through a grease trap and ends up in a water tank where it is assimilated by banana trees. Banana trees are well suited, as one adult tree consumes up to 15 litres of water per day. Other types of vegetation that use a lot of water, such as papaya or ginger can also be used as long as they have relatively shallow root systems that do not damage the sanitation structure. It is important to not use soaps with strong chemicals as it might affect the plants.

Figure 11 Grey water sanitation system using banana and papaya trees

The system to treat black water, the waste water from toilets, has been created by Tom Watson and has, subsequently, been adapted by several Brazilians. The system uses three stages, in the first two it relies on anaerobic decomposition of waste by micro-organisms. The nutrients assimilated by the micro-biotic community and the water are taken up by plants in stage three, becoming part of the ecosystem. Water is transpired by the plants and goes back into hydrological cycle. Food from this system can safely be eaten, but low-growing plants, such as lettuce, should be avoided, as the food might be in direct contact with the effluent and contamination could occur.

Another system that is used is a dry compostable toilet. This system is a perfect option in places where water is limiting resource. It doesn't require anything, only a cultural adaptation. After each deposit of waste, sawdust is added to keep the toilet dry. The faeces, urine, toilet paper and sawdust are left to ferment for 6 months, after that it is used as fertiliser on the land.

Figure 12 Schematic drawing of compostable toilet on the left, and volunteer Lucas taking out the compost during the PDC course on the right

Permaculture

Permaculture embodies a holistic approach to designing regenerative systems by using nature as a guide, fostering cooperation and connections within ecosystems, and seeking solutions that promote abundance and harmony (Macnamara, 2012). Using permaculture human habitats are seamlessly integrated with the environment.

The term was first coined in the 1970s by Bill Mollison and David Holmgren and is bringing ancestral wisdom back to life, in a modern fashion (Mollison & Holmgren, 1978). At its core are three ethics: *earthcare*, *peoplecare* and *fair share*, followed by principles, techniques and methodological design processes. The ethics can also be seen as life ethics, as they are central in many cultures and religions.

Earthcare emphasizes the respect to all life, recognizing that our survival is inherently linked to the health and well-being of the interconnected global ecosystem, where actions have ripple effects worldwide, a concept also known as tele-coupling.

Peoplecare encompasses nurturing both ourselves and others sustainably, fostering collaboration for mutual benefit, cultivating community, purpose, and belonging.

Fair share promotes equality, justice and abundance, now and for future generations, in short: some for all, forever. It advocates to live within planetary limits and give away surplus, as there is plenty to share around.

From these central ethics, it becomes clear that permaculture is far more than an agricultural method. In its holistic approach, it recognises that human well-being in connected to the health of ecosystems. Permaculture fosters a comprehensive approach to sustainability that encompasses social, economic, and environmental dimensions.

In his 2002 book, Holmgren redefined the permaculture principles into the following set of 12 (fig x below)(Holmgren, 2002). They can be applied to all kinds of systems, from a producing garden, to personal health, transport or communication. However, they are predominantly applied and implemented within small-scale agricultural settings.

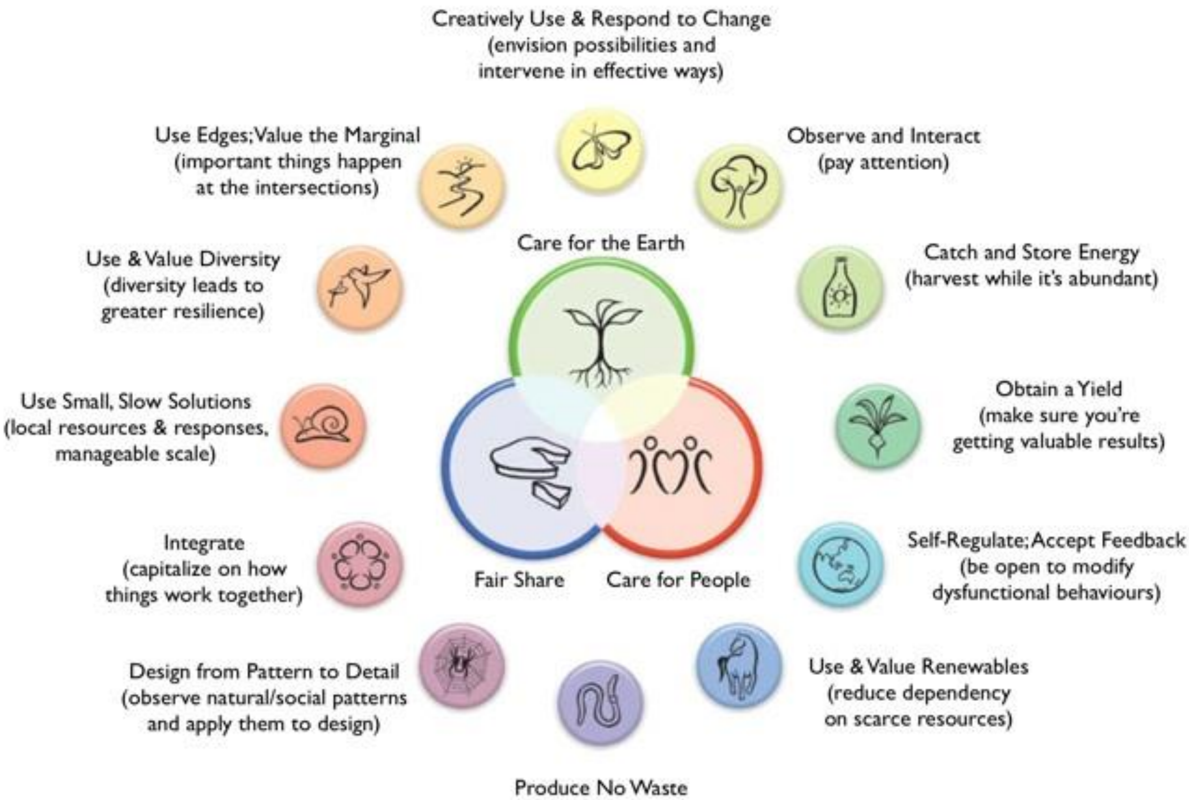

Figure 13 Permaculture principles posed by Holmgren, 2002

To provide a practical framework for organising a permaculture design it is beneficial to use zones, sectors and the slope. Holmgren's zoning system consists of several numbered zones, radiating outwards from the centre of human activity, which is often the home or main living area. Each zone is designated based on its proximity to the centre and the frequency of human interaction and maintenance required. So that zone 1, directly surrounding the house, contains elements that need daily or weekly care, such as a vegetable garden or compost bin, up to zone 4, that requires minimal management and is left to natural processes.

Sectors are external influences or forces that affect a site, these include: solar aspect, wind patterns, water flow, wildlife corridors, and more. By taking these into account, potential challenges and opportunities can be anticipated and integrated into the design, in order to work with, rather than against, the natural dynamics of the landscape. The slope of the land has important design implications for water capture, retention and distribution, as well as erosion control.

The above-stated ethics and principles form the foundation of the Morada Ekoa philosophy, guiding its practices and approach to permaculture. The design methods have been used and applied to guide the design process when the project started in 2008. Over the years, the practical implementation of the outlined plan has evolved into its current state, see figure below. For instance, in the beginning clusters and groups of producing trees were dotted across zone 2 &3, creating a more natural landscape, the so called 'romantic' approach. The new agroforestry systems are organised rationally in lines, making I t easier to manage weeds and harvest food.

Figure 14 Permaculture design of Morada Ekoa following Holmgrens zoning methods, on the left the design at the start in 2008, on the right drawing made during winter PDC of 2024

There is a big overlap between permaculture and other forms of agriculture that aim to promote sustainable and regenerative agricultural practices, such as, agroecology, agroforestry, syntropic agroforestry, food forests, and bio-dynamic or organic agriculture. At Morada Ekoa (syntropic) agroforestry and food forests practices are also employed, therefore I will articulate the distinctions to maintain clarity within the text.

Permaculture underscores a holistic methodology that applies to all facets of Morada Ekoa, encompassing food cultivation, sewage treatment, bio-construction, and community cohesion, thereby serving as the overarching philosophy. Agroforestry is defined as "a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic, and environmental benefits for land users at all levels" (FAO, 2022). There are many different types of agroforestry, from simple tree integration into monoculture systems to complex, multi-layered food forests. Food forests can be defined as:

‘Human-designed productive ecosystem, consisting of multiple layers and a rich soil system that mimics a natural forest, with a great diversity of perennial, woody species, of which parts (fruits, nuts, seeds, leaves, branches) serve as human food’ (Green Deal Voedselbossen, 2017).

Syntropic agroforestry is designed by Ernst Götsch and is mainly practiced in tropical climates (Andrade et al., 2020). It is a type of food forestry that has a strong emphasis on natural succession and focuses on the restoration of degraded and marginalized land. In the figure below, the evolution of our current arrival at agroforestry is depicted. Natural succession leads to a forest in its climax state, after which humans deforest the land to plant crops, after many decades of erosion the land becomes poor and degraded. Consequently, it is restored into forest using agroforestry management practices and natural succession.

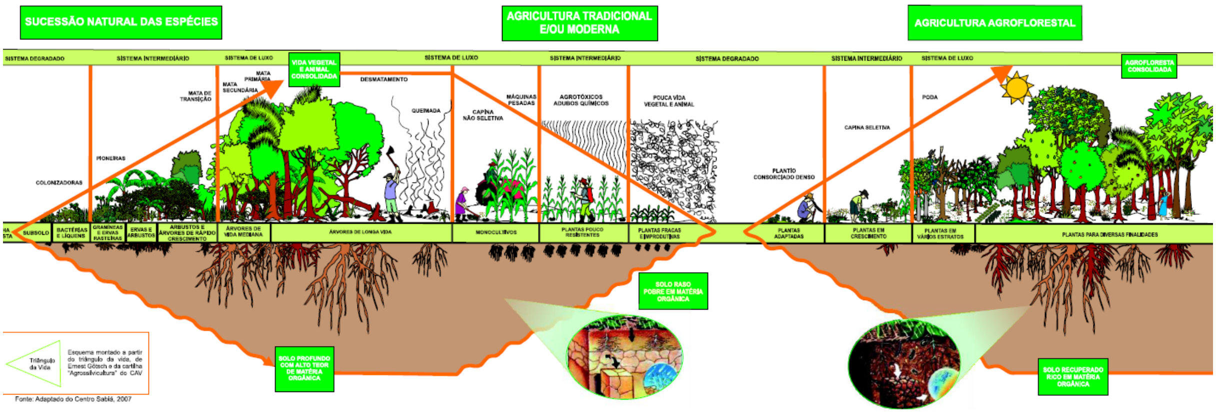

Figure 15 Dynamics of natural succession in natural ecosystems, agro-ecosystems and agroforests. (Based on the Triangle of life by Ernst Götsch)

The land of Morada Ekoa is comprised of acidified, nutrient poor, sandy soil that pose hard conditions to plant growth. This environment is though for the establishment of a young, developing food forest, necessitating considerable initial effort and external inputs to accelerate the natural succession processes that build up a healthy soil. Over time, various methods have been used to initiate a new section of agroforest, yet they fundamentally come down to the same core steps. This includes removing grasses and other strong weeds, enriching the soil with organic matter and nutrients, and covering the planted area with organic material. As the young system matures, nutrients, predominantly in the form of mulch, dried grass, or other forms of organic matter, are continuously added. Mulch serves as a form of organic carbon that improves the soil structure, supresses weeds and reduces evaporation, thereby alleviating environmental pressure on the growing plants. Margaridão (*Tithonia diversifolia)* plays a key role for mulch supply, as it grows rapidly, even on nutrient poor soils, with abundant, nutrient-rich vegetative matter.

The most recent section of food forest, comprised of three 12-meter-long rows, was created using the following method (pictures in appendix 5). In the first row, half a meter is allocated for a pathway filled with stems and thick branches of eucalyptus, while the remaining two rows have a meter of space between them, followed by another half-meter pathway of Eucalyptus wood. The top 10-20 centimetres of soil in the middle row are manually tilled, removing grasses, but retaining small shrubs. This layer of soil is then mixed with 5 kilograms of lime, 2 kilograms of ground mussel shells, 1 kilogram of marble stone flour, 50 kilograms of purchased organic matter, and 35 kilograms of purchased poultry manure and bedding organic fertilizer (comprised of: 2% N, 3.4% P_2O_5, 2.5% K_2O, and 22% organic carbon). Once mixed, young saplings are planted, seeds are sown, and the entire area is covered with a 5-10 centimetre layer of dried grass. The design of this system is depicted in figure x, below.

The agroforest system is designed to make use of natural succession, the fast-growing species, such as broccoli, sugarcane, banana, and mandioca, take up the space first. The slow-growing tree species, such as, orange, nona and Ipé, will take over in time, creating a multilayered system.

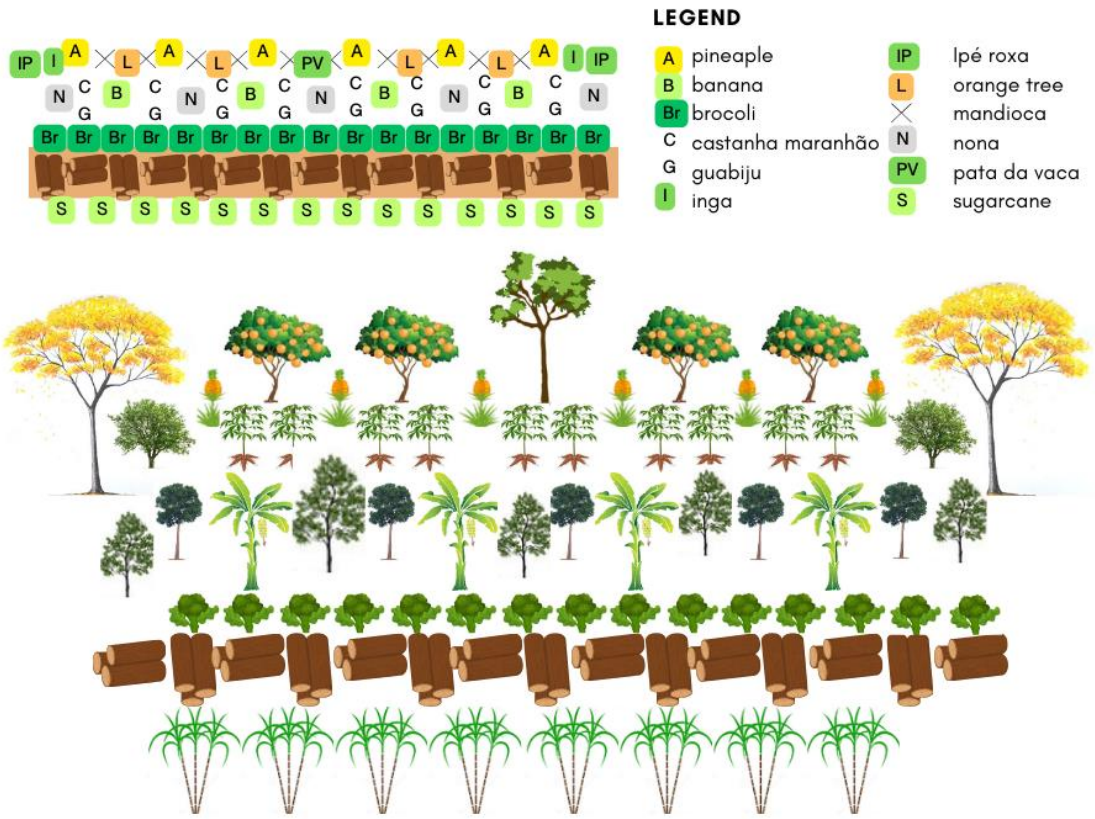

Figure 16 Design of one 12 x 3 m line of agroforest system next to casa spirulina, Morada Ekoa. Design of system is expressed using symbols, the artistic expression of the matured system is not to scale, both in size and time.

Pruning is another important management tool to speed up natural succession, as much emphasized by Ernst Gotsch and syntropic agroforestry. Species are pruned according to criteria such as stratification, life cycle, and succession (Pasini, 2019). The idea is to create an environment of constant cycling and increase of organic and inorganic nutrients, maximizing photosynthesis and accelerating the system's ability to metabolize and convert energy into more complex forms of life.

The constant pruning, and systematic cutting and positioning of the organic matter on the soil stimulates the action of organisms, speeding up the transformation (Pasini, 2019). The pruned plants invest in new growth both in the aerial part (branches and leaves), and more importantly, in their roots. The pruning also changes the biochemical composition of enzymes and hormones in plant roots, which indirectly favours greater retention of water and nutrients.

Species that have the capacity to produce large amounts of biomass, such as margaridão or eucalyptus, should always be included in an agroforestry system. Margaridão and eucalyptus naturally grow in poor conditions and have a rapid metabolism, even on degraded soils, allowing them to process large amounts of energy in short periods of time. These exotic species, viewed by conservationists as invasive pests, can be used to recover the soil fertility, so that more demanding trees can establish themselves in the future.

Education

Morada Ekoa aims to serve as an example to interested individuals and organisations. They offer different educational programs, the major being the Permaculture Design Course (PDC) that is organised biannually. The PDC covers theory about ethics, principles, and design processes, but has a strong focus on practical implementation of permaculture techniques. The end goal of the PDC is for participants to implement all the newly learned permaculture skills in a design of their own that is presented to the group.

Next to the PDC, there are about two bioconstruction courses offered per year. Here participants learn theory about building with adobe, again with a strong focus on practical experience. Throughout the year, there are visits from schools classes, ranging from primary to higher education. They always start with some background on the project and a tour of the land, followed by some practical class, often involving bioconstruction, to give the students something to actively learn with.

Figure 17 Participants making plaster during bioconstruction course

Some of the students that once participated in the PDC program took their study to practice and started their own permaculture projects, some only a kilometre away. The ideas that were planted by Morada Ekoa have taken root and flourished, now scattering their own seeds of inspiration.

Ecosystem services

Ecosystem services (ES) have been defined as the benefits that humans derive from natural ecosystems (Millennium ecosystem assessment, 2005). These benefits include provisioning, regulating and cultural services that directly affect people and supporting services that maintain the other services (see fig x). An ecosystem is a dynamic complex of interactions, as are its services, a dynamic complex of interactions that work synergistically. They enhance the functioning of one another, therefore restoration of one service can lead to more improvements.

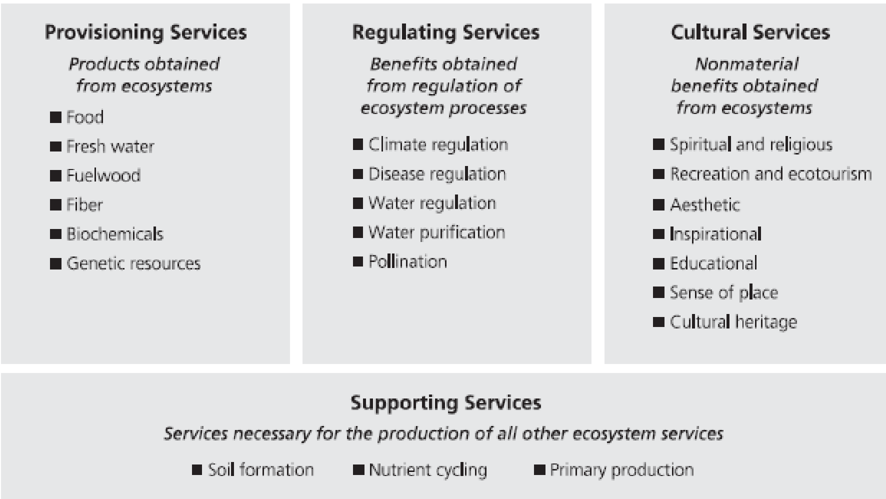

Figure 18 Reprinted from Millennium Ecosystem Assesment (2001) Ecosystems and human well-being: a framework for assessment.

Over the years different theoretical frameworks have been developed to conceptualise, classify and model ecosystem services, such as the Cascade Model. The cascade model, depicted in fig X below, explains the pathway for delivering ES from biophysical structures at one end to benefits for human well-being on the other (Potschin & Haines-Young, 2011). It can be used as a tool to help understand more clearly the Ecosystem Services concept and the ways nature can influence people's well-being. The model differentiates between benefit and value, as benefit being the thing that changes people's well-being and value, as the importance they assign to it. This value can be expressed in monetary values, or using moral, aesthetic or spiritual criteria. The values make people and societies chose to act (or not) to modify or manage the pressures on ecosystems and ultimately the benefits they deliver to society.

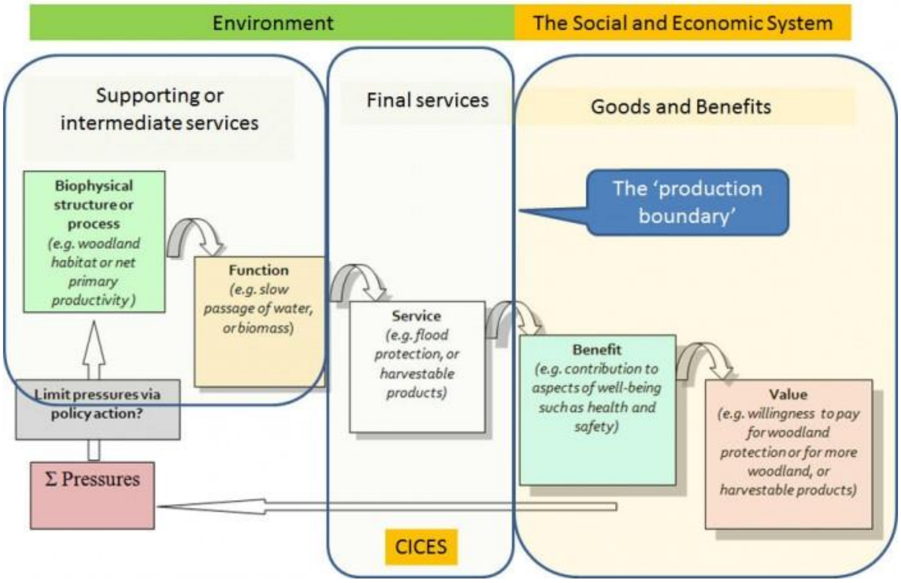

Figure 19 ES cascade model from: Potschin, M. and R. Haines-Young (2011), accessed conceptual from https://cices.eu/supporting-functions/

The cascade model provided the framework for the Common International Classification of Ecosystem Services (CICES). CICES version 5.1 has been widely used in the academic community, it has been cited in scientific literature over a 1000 times since 2018 (CICES, 2024). CICES has been designed to help measure, account for, and assess ecosystem services (Haines-Young & Potschin, 2018). It tries to classify final ecosystem services, the outputs of ecosystems that provide benefits to human well-being (see fig x above).

CICES recognises the main categories of ecosystem outputs to be provisioning, regulating and cultural services, however, it does not cover the so-called 'supporting services' originally defined in the Millennial Assessment. The supporting services are treated as part of the underlying structures, process and functions that characterise ecosystems. Since they are only indirectly consumed or used, and may simultaneously facilitate many 'final outputs', it was considered that they were best dealt with in environmental accounts and mapping in other ways (Haines-Young & Potschin, 2018). CICES uses a five-level hierarchical structure, in which each level becomes progressively more detailed and specific. The hierarchical nature makes the model a good tool for ecosystem accounting at all kinds of scales, even when the exact end of use is not known.

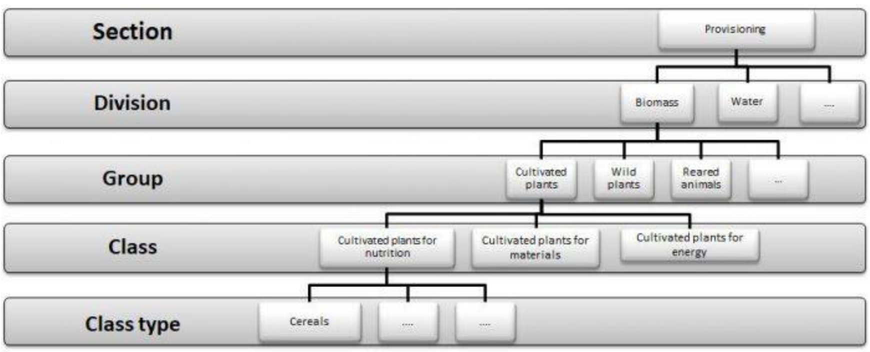

Figure 20 Overview of the hierarchical CICES framework

I used the CICES framework to map the Ecosystem Services generated by Morada Ekoa, coming to the following overview of ‘class’. All of these services are interlinked in a complex network of interactions with management practices and external influences.

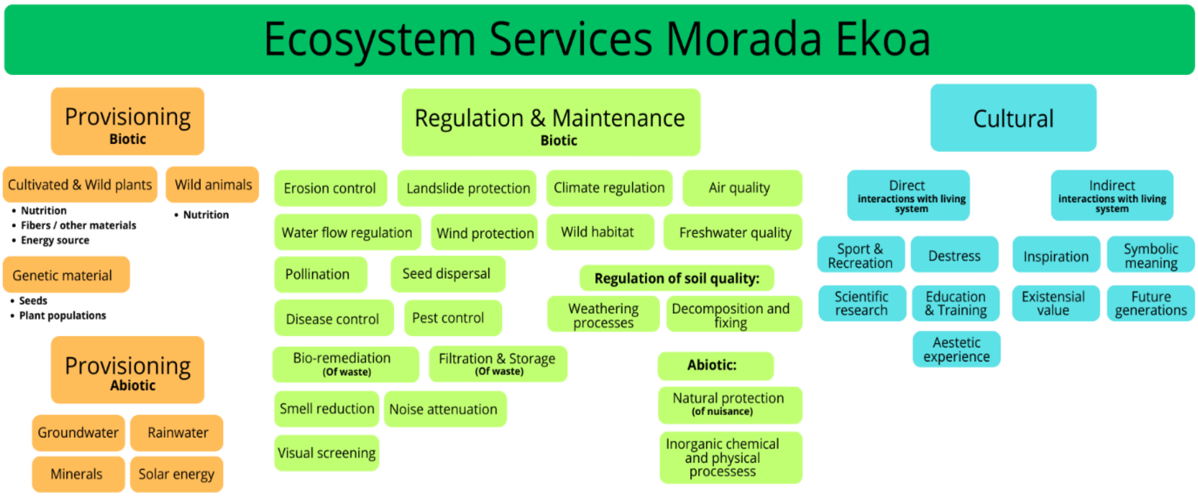

Figure 21 Ecosystem services of Morada Ekoa, mapped using the CICES framework

There are many ecosystem services generated and used at the Morada Ekoa, some are quite actively exploited, such as food generated by the agroforestry systems (*nutrition from cultivated or wild plants*). Most regulating services are more indirectly affecting well-being, for instance pollination of plants by insects or birds ensures that fruits are grown, and pest control guarantees that plants stay healthy and that some food is left for human harvest. Some cultural ES values are being expressed directly, such as sport and recreation, by going paddle boarding in the little river, or education and training, by hosting courses.

It is good to note that all of these services are provided by nature for free, as long as humans allow conditions conducive to life. The monetary value of ES are often calculated by assessing the costs that would be incurred if the services were not provided naturally. In this manner the cost of the artificial alternatives or restoration of the service becomes its monetary value. For example, in the provinces Shaanxi and Sichuan of China natural pollinators like bees have become scarce, forcing apple and pear farmers to resort to manual pollination: manually transferring pollen from flower to flower using a brush. Having to resort to manual pollination leads an enormous rise in labour costs and clearly illustrates the economic value of pollination.

Another famous example is of New York city’s drinking water supply, that was not meeting its water quality limits in 1997. The options were to build a massive water treatment plant, costing an estimated $6-8 billion plus $300-500 million annually in operational costs, or spending $1.5 billion to preserve the natural ecosystem that provides water purification services (Kenny, 2006). When stated in these terms, the choice became obvious to decision makers. So, the city acquired land, restored riparian buffers, wetlands and forests and reduced agricultural pollution runoff, to prevent the need for an expensive treatment plant.

Another technique to value ES is the contingent valuation method, which relies on surveys to directly ask individuals about their preferences and willingness to pay (WTP) or willingness to accept (WTA) compensation for changes in ES (Whitehead & Haab, 2023). Using these two methods, all the ES generated at Morada Ekoa could potentially be converted into an economic value. For the ES, *cultivated and wild plants for nutrition*, the monetary value is rather easily calculated, this is further discussed in the next chapter.

Possible, the two most important ES at Morada Ekoa are *Cultivated & Wild plants for Nutrition* and *Decomposition and fixing.* To illustrate how these two services are affected I've constructed the following network of interactions. There is some effect of management actions on the ES, but the services are mostly regulated by nature.

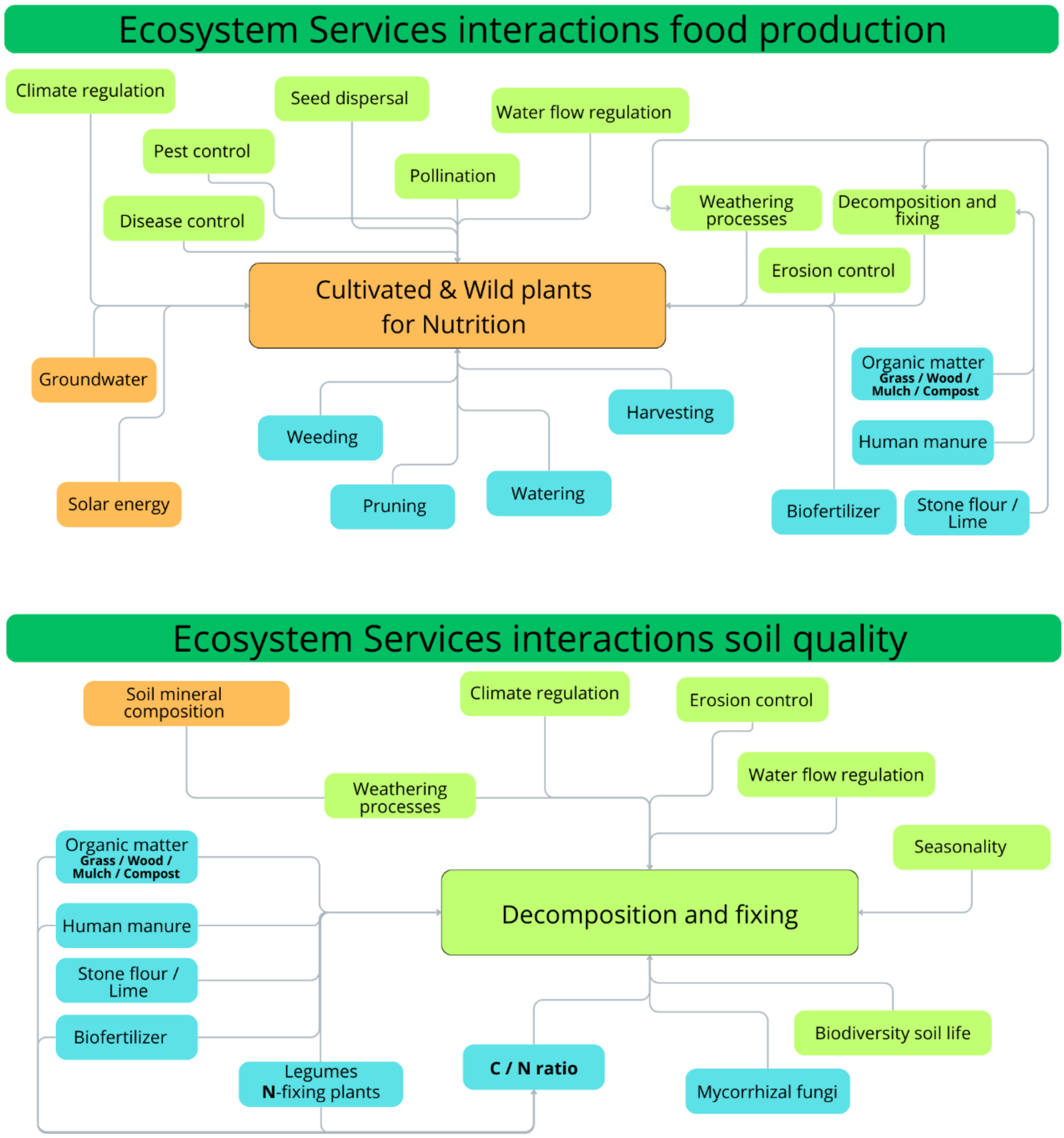

Figure 22 Ecosystem Services interactions. In green are other ES, orange abiotic factors and in blue human management actions

Value creation

Now that the context of the Morada Ekoa project has clearly been described, I will dive into the analysis of the economic, social and ecological values that are created. There has been a focus on the creation of ecological values, I examined the biodiversity and the functioning of the soil system in more detail. I provide suggestions and advice on all the different facets based on the assessment.

Economic values

This small-scale permaculture community creates various economic values, both directly and indirectly. The indirect values may not always be immediately quantifiable in traditional monetary terms, but they do contribute to a more sustainable and resilient local economy while promoting environmental regeneration.

The main economic inputs of Morada Ekoa are in ecotourism and education. The chalets on the land are rented out, preferably to contributing community members that stay for longer time periods. The revenue when all three houses are rented out is about 2500 reais (€500) per month. In the high season and during public holidays, the houses can be rented out for a higher price, approximately 200 reais per day.

Morada Ekoa has different educational programs that generate a substantial part of the income. The PDC costs 1300 reais per person and used to have an average of 10 participants in summer, and 6/8 in winter. In recent year the number of participants has been on decline, which could be related to the increase in online permaculture courses. About one third of the revenue goes to hiring staff (cook and external teachers), one third to food, energy and materials, the remaining one third is revenue for Morada Ekoa. Next to the PDC, there are about 2 bioconstruction courses offered per year, they cost 300 reais per person and have an average of 6 participants. Lastly there are schools classes, ages ranging from primary to higher education, that come and visit throughout the year, however, these are usually hosted without charge.

An additional revenue stream stems from offering consultations in permaculture, wastewater management, environmental design, and sustainability to external parties. The magnitude of this economic influx varies and hinges on the level of effort dedicated to acquiring clients.

Sustainable agriculture is one of the main pillars of Morada Ekoa and a diverse range of food is produced in the agroforestry system. Currently, the entire food production is consumed by the community, there is no surplus to be sold. The production has been quantified for the months April and May, generally the best producing months of the year. From April 9 to May 17 a total of 258 kg of food has been produced from 38 different types of plants, the detailed table is attached in Appendix I.

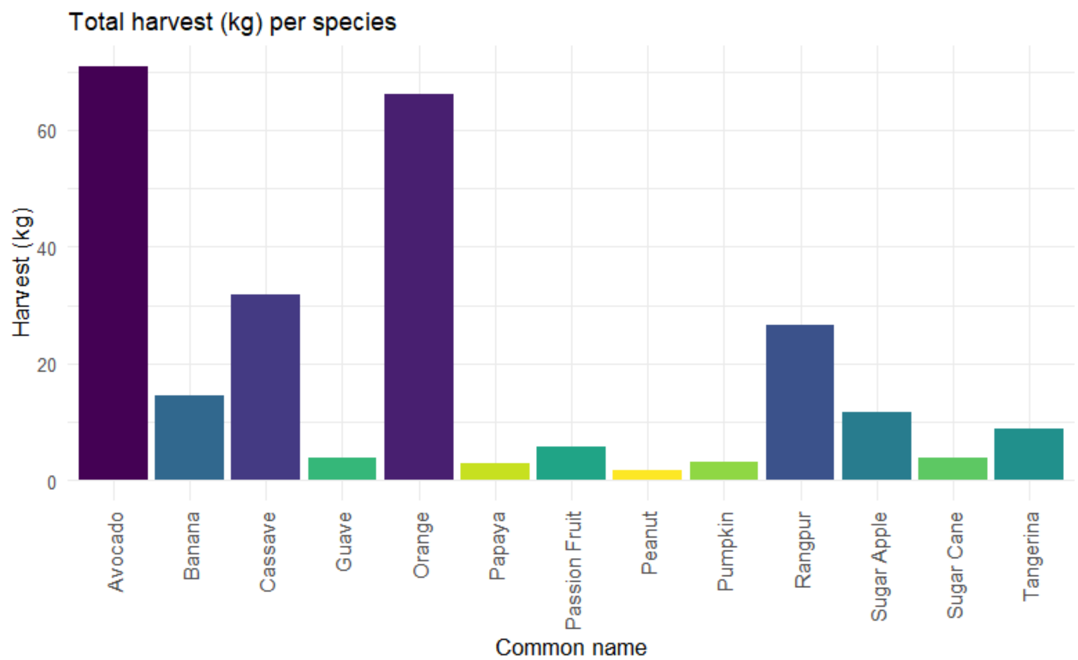

Figure 23 Total harvest at Morada Ekoa of months May & April 2024, only products of which more than 1kg are harvested are depicted

Total harvest from May 9 to June 9 of which more than 1 kg of total product was harvested, is depicted in the figure above. Avocado and orange yielded the biggest harvest, followed by cassava, rangpur (orange lime) and banana. The price of the produce at the local market and a nearby organic market was used to calculate the economic value of the total harvest. In the figure below, the total value of all products, of which a minimum of 25 $R was harvested, is shown.

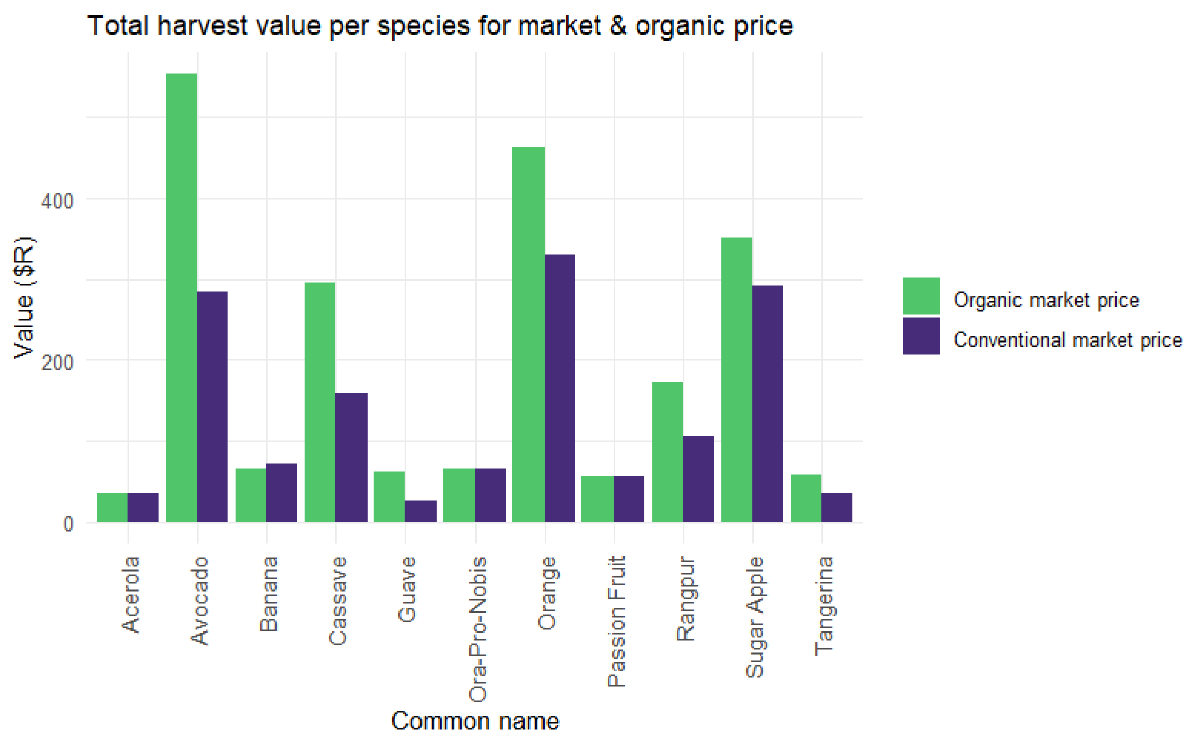

Figure 24 Total harvest value of produce collected in months May and April at Morada Ekoa both conventional and organic market price are shown.

Looking at the value of the harvest, avocado and orange still contribute the major portion, but some other crops such as sugar apple (*Annona Squamosa),* acerola or ora-pro-nobis also arise. These, so-called cash-crops, have a high monetary value for their weight, thus, while only making up a small portion of the total harvest weight, they make up a larger portion of the economic value. By focusing more on the production of these cash-crops, the economic value of the produce could be substantially increased.

The total monetary value of this two-months harvest is 1600 $R at the conventional market and 2350 $R at the organic market. To extrapolate this value estimate to calculate its contribution of to the total economic input, I will use an approximate average harvest 1000 $R per month. In a good year the economic input of the different sources would be approximately 50% rental, 25% courses and 25% food production (with a good-years estimate of about 23.000 in rent, 10.500 in courses and 12.000 in food).

Next to these flow there are economic values that are harder to express in monetary terms, such as the creation of ecosystem services. The potential monetary value of all these services could be calculated and would be some orders of magnitude larger than the actual economic input. This stresses the major importance of the services provided for free by nature that benefit our well-being. For instance, one ES is the aesthetic appeal and productivity of the landscape, increasing these has seriously increased property values of the land in the long term. It is hard to put an exact price on it, as all of the land in the area has increased rapidly in price. But, the whole land was bought in 2008 for R$ 80.000 and would now be worth well over R$2 million.

Organic farming methods emphasize soil health, biodiversity, and natural inputs, resulting in organic produce that often contains higher levels of nutrients, antioxidants, and beneficial compounds compared to conventionally grown food, without any added toxins (Miller, 2013). Moreover, locally grown foods retain their nutrient content better, as they do not spend some days in a truck. These factors contribute to health benefits, potentially reducing the risk of chronic diseases such as obesity, diabetes, and cardiovascular disease (Miller, 2013). Furthermore, exposure to natural environments has been linked to reduced stress, improved mood, and enhanced immune function. Therefore agroforestry could lead to decreased healthcare costs and increased productivity.

Currently, all the food is consumed by the community, there is no surplus to be sold at a market. If you would want to increase the economic input, it might be interesting to produce a surplus of certain crops that could be sold to generate an additional stream of income. It would be best to focus on cash crops, products that are relatively worth a lot of money, such as macadamia or nona. There is already a focus on some of these, like Atlantic forest fruit trees like Nona, Butia, Acerola, Jussara or Jabouticaba, but they take a long time to grow.

Another way to increase the value of some of the harvested products is to process them into artisanal crafts, like orange marmalade, dried herbal tea or butia icecream. These products could be sold by you or a friend at a local organic market, such as the saturday Garopaba market. But, as has been suggested a couple times, you prefer to not take the food to the people, but the people to the food, by hosting a small café once or twice a week. This could be a good place to sell artisanal products and people could be taken into the field to collect their own organic food directly, thereby the experience aspect can further increase the value of the food. For instance, you could turn it into some sort of treasure hunt if you make a little flyer or booklet with all the edible plants, so people know what they can harvest.

Many different projects are being carried out simultaneously and it can be hard to find the time and focus for all of them. Therefore, to actually implement the café it would be advised to find a partnership with someone who has the time and energy to run the café. In this partnership you would provide the raw resources: the location, materials and food, and the partner would be responsible for the café. If this idea would be further explored, you could focus on planting more crops that would be needed in the café.

Bamboo is collected, treated and dried for use sporadically, but these products could also be sold. Next to that, if the plant nursery is cleaned up and organised, it could be another revenue stream. If the café would be established and Morada Ekoa would receive more visitors, it would be easier to sell these products. Moreover, the same partnerships can be sought for these projects, maybe the friend that works a lot with bamboos would be interested to explore this idea.

Lastly, my advice would be to plant a lot more agroforest and try to work with species that grow well on these soils, you would know best which these are after 15 years of experience. At the moment only about 30% of the land is covered, there is still a lot of room to plant more producing species, for instance the area next to the entrance, around the chickens or on the top of the hill. Ofcourse, lot of energy and time goes into a developing agroforestry system, but in these areas you could focus on less demanding species. You could plant native species that might only need management once or twice a year, and would yield valuable nuts or fruits in 10, 15 or 20 years.

Social values

The Morada Ekoa community generates a range of social values that contribute to sustainability and community well-being. First and foremost, the reconnection of people with their planet. Re-establishing this connection is good for the health of both people and planet and will preserve the earth for future generations. Moreover, the creation of a community results in collaboration and sharing resources, a sense of belonging and mutual support positively impacts well-being. The community and its cooperation can be seen as social capital.

Figure 25 Morada Ekoa family

Morada Ekoa serves as a permaculture institute by offering courses on bioconstruction and permaculture and teaching permaculture and sustainability to school classes. By showing alternative, sustainable ways of living they introduce people to a new way of thinking, hopefully changing some minds along the way. By serving as an example they become a source of social capital.

They host volunteers, which help out on the farm and in the household and become part of the community for a short period of time. The volunteers take inspiration and spread it as they continue their journey. Besides volunteers, study projects are welcomed with open arms, further expanding the knowledge and network around Morada Ekoa.

Another practical example of the social values generated at Morada Ekoa has been the opening of the river system, the transformation of which can be seen in figure 3 in the section *History*. By clearing out and managing some of the exotic grasses the lake and river has been re-opened. This has revived essential ecosystem services related to freshwater quality and biodiversity, as well as cultural services, enabling visitors and neighbours to go paddle surfing or fishing, in this way contributing to local social values.

Figure 26 Paddle surfing in the lake (banheida)

The main piece of advice around the social values would be to take a completely new approach to attract enough participants for the courses. As mentioned, the number of participants has been on decline recently, which could be due to the rise of online courses. To ensure the qualitative continuation of the courses it is important to have a sufficient amount of participants. My advice would be to start earlier with the promotion and to set a dead-line for the sign-up. The dominant means of promotion is now Instagram, other channels could also be investigated, such as facebook, the website, and blogs or channels of related activities. Moreover, it has been proposed to find a sponsor that wants to compensate for its polluting activities, such as a fuel station or heavy industry, by sponsoring the course for people with a tighter budget. This activity should be planned on a longer time-scale, interested parties such as environmental science students should be found and different sponsors should be approached with a sales-type approach, clearly outlining what is in it for them.

The same applies to writing a proposal for funds for a longer, organised elementary or high-school program. Plan out the project, clearly state learning goals and benefits to the kids' education, to sell the project to government sources.

Ecological values

The ecological values created at Morada Ekoa have grown substantially since the property has adapted from agriculture/pasture to biodiverse permaculture. In this section I will offer an assessment of the changes to biodiversity and soil functioning after 15 years of agroecological management, and analyse the different fertiliser inputs used.

Biodiversity

To get a measure of the increase in biodiversity all human-planted and managed plant species where identified, producing a species list of mostly functional product-supplying plants (i.e. food, timber, medicines). Plants were identified in the periods Oktober – December, and March – June, with expert help from Felipe, and online research to affirm the species. Species scientific and common Portuguese and English names are recorded, as well as, the main function and origin.

A total of 144 different species was recorded, in 26 different orders, spread over 49 different families (see APPENDIX II). The three most represented families are the *Fabaceae* (legumes), *Myrtaceae* (tropical fruit trees), and *Poaceae* (grasses). Out of all species 42% is native to brasil, of which 30% is also locally native. From all the species recorded, 32% produced a resource that was harvested in the months April – May. For each species the main function was determined, in 14 cases two functions are selected, yielding the following table.

Table 1 Main function(s) of the 144 plant species identified at Morada Ekoa

Function	***Number of species***
food	80
biomass	23
aromatic	20
ornamental	15
medicinal	13
construction	5
soap	1
Toilet paper	1

From the main functions it becomes clear that more than half of all species are planted because they produce food. The function biomass may be biomass to relocate as fertiliser input, such as mulch from margaridão or elephant grass. But, it is also used for biomass as ecological function in the location where the plant is growing. The plant is a part of the ecosystem and host for hundreds of other organisms that live of its biomass (i.e. leaves, woody parts, nectar, fruits, sugar excreted by roots, etcetera). Most aromatic species also have some sort of medicinal properties, this is not always indicated as two functions. Lastly, all species have an ornamental function, but for some, predominantly, exotic species, this was selected as the main function.

Many plant species, such as grasses, herbs, mosses, ferns, or bromeliads, without a direct human function, are not included in this list, due to limited time and expertise to inventory the complete diversity. If the complete plant biodiversity would be incorporated, it is estimated that the total number of species would easily be twice the current number. Nonetheless, the plant species diversity recorded here is a significant improvement compared to vegetative diversity at the start of the project. At the start there was just a small number of some native pioneer species, such as vassoura, butia and guave. Most the land was made up of mandioca and eucalyptus plantation, with some pastures on the side.

The increase in vegetative biodiversity has led to habitat complexity, resulting in the expansion of ecological niches. With more niches available, there are more opportunities for different species to use resources and interact without direct competition. Consider for instance the diverse array of symbiotic relationships that each of these plants foster with bacteria, fungi, pollinators, and herbivores. Consequently, the planting of a wide variety of plant species has enhanced biodiversity all the way up the food chain.

Even exotic species such as the eucalyptus and margaridão can deliver a valuable contribution to biodiversity. Both provide abundant amounts of nectar, attracting multiple species of hummingbirds and many kinds of insects, which in turn become food for an array of other insect and bird species. However, it is important to keep managing the margaridão, bamboo and eucalyptus, so that they do not take over. They are valuable resources, but do not provide as much habitat for wildlife as native trees do. Therefore it is good to take out margaridão root and all in places where it has served its purpose, and to not plant more bamboo than you will need and be able to harvest, this will also reduce the amount of time spend managing these species.

Approximately 20% of the land has minimal management practices and is left alone to natural processes. This area provides valuable habitat for all kinds of species, thus improving biodiversity. Overall, almost all of the management practices to improve biodiversity are already implemented at Morada Ekoa. Some opportunities to further improve the biodiversity would be to provide more nesting availabilities for birds and bats, since most of the trees on the land are still young and small and have limited nesting holes, nest boxes could be interesting. This could also be done for insects by building a small bioconstruction wall without additives, solely for the purpose of providing nesting habitat.

There are already various flowering species throughout the season, but it could be interesting to create a herbaceous wildflower area. This could become a beautiful eyecatcher and provide even more availability for nectivores, and it would best be executed with a variety of native species in a central area.

Lastly, a more radical idea would be to look at options to reintroduce a big herbivore in the banheida water system, such as capybara, that could help to manage the proliferation of exotic grass.

Soil functioning

A widely used and accepted definition of soil quality is stated by Doram and Parkin (1994) as: "Soil quality is the ability of a specific soil type to function, within the limits of the managed or natural ecosystem, as sustaining the productivity of plants and animals or increasing the quality of water and air and promoting human health". This definition will be also be used to assess the soil quality at Morada Ekoa. I will first provide a theoretical framework of processes underlying proper soil functioning, followed by results from the chemical soil assessment, the pfeiffer chromatography and lastly the effects of different fertiliser sources.

Theoretical framework

The soil is a realm where solid, liquid, gas and biology all interact, at spatial scales the span many orders of magnitude (Schmidt et al., 2011). This complexity of the soil system makes it difficult to capture in one conceptual model. To help interpret the results of the soil tests and understand what the application of different fertiliser sources does to the functioning of the system, I will frame some of the current scientific knowledge on soil processes.

Soil microorganisms are essential to soil functionality, they influence nutrient acquisition, nitrogen and carbon cycling, and soil formation (Van Der Heijden et al., 2008). The microbial community of the soil is incredibly diverse, one gram of soil is estimated to contain 10-100 billion bacteria of 6000-50.000 species, and up to 200 meter of fungal hyphae. Microbes can directly affect plant productivity, in the case of nitrogen-fixing bacteria or mycorrhizal fungi that supply nutrients in exchange for carbon, or indirectly, via the action of free-living microbes that alter rates of nutrient supply.

Erosion reduces the microbial diversity and causes shifts in soil bacteria composition, in some cases leading to more N-fixing bacteria (Qiu et al., 2021). Rather than just species diversity, the community composition and related functional diversity seems more important for soil ecosystem functioning (Bardgett & Van Der Putten, 2014). For instance, reductions in decomposer functional diversity consistently showed slower rates of litter decomposition and carbon and nitrogen cycling. Even though microbial functional diversity might be the most important factor contributing to soil functioning, species diversity does offer redundancy of functional traits, especially when processes such as erosion or disturbance cause shifts in the community composition.

Improved DNA techniques of recent years have revealed a lot of new information, such as a recent study showing the importance of non-living microbial biomass to the formation of soil organic matter, in some cases up to 50% of total OM stock (Sokol et al., 2022). The figure below from their study gives a good representation of the complexity of the soil microbiome and cycling of organic matter.

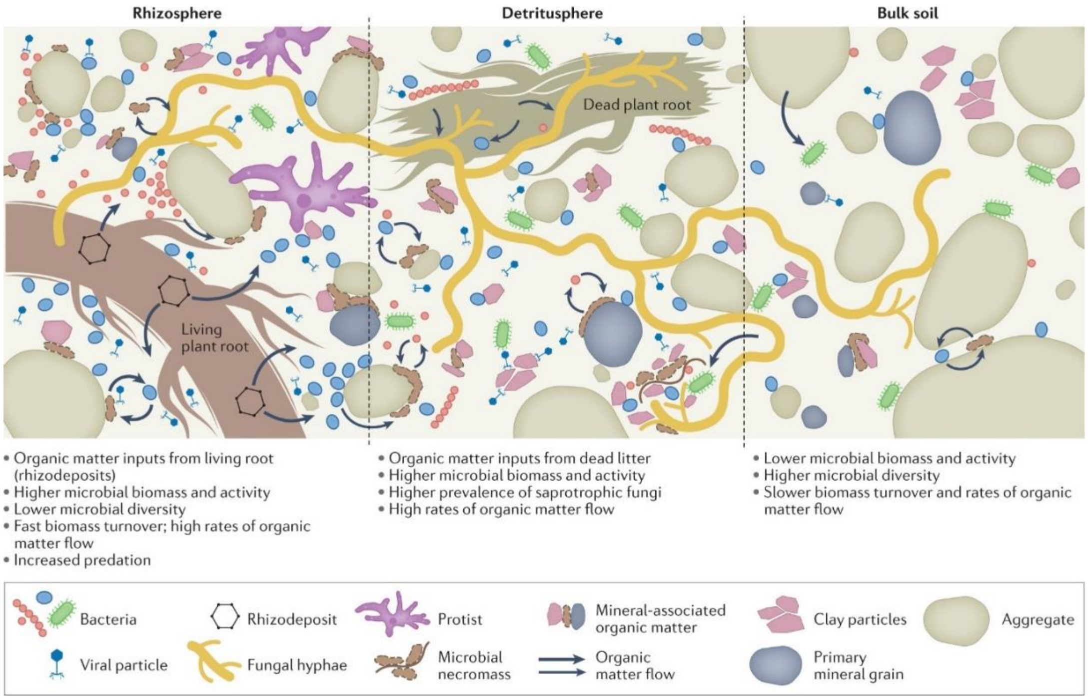

Figure 27 Composition of soil microbiome and its role in cycling organic matter. From (Sokol et al., 2022).

As illustrated above, complex organic carbon compounds, such as acids, sugar and protein enzymes, are transferred from plant roots into the surrounding soil ecosystem and to mycorrhizal fungi. These fungi receive 'food' from the plant and in return supply water and nutrients from locations in the soil where the plants roots do not reach, thus greatly enhancing a plant's ability and productivity. The fungi in turn excrete carbon-containing residue into the surrounding soil that can serve as food for other microbes.

The processes performed by soil microbes that impact nutrient availability and plant productivity are shown in figure X below. Organic nutrients are decomposed by bacteria and fungi and become available for uptake directly or via mycorrhizal fungi, or become immobilised into living or dead microbial mass (Van Der Heijden et al., 2008). Ecto-mycorrhizal fungi also have access to deliver organic nutrients directly and even some plants can acquire organic nutrients directly.

Nitrogen can be lost from the soil when denitrifying bacteria transform ammonium into gas, or it can leach when nitrifying bacteria transform it into the more mobile nitrate (Van Der Heijden et al., 2008). Nitrogen gas can also be fixed into ammonium by symbiotic and free-living bacteria, making it available to plants.

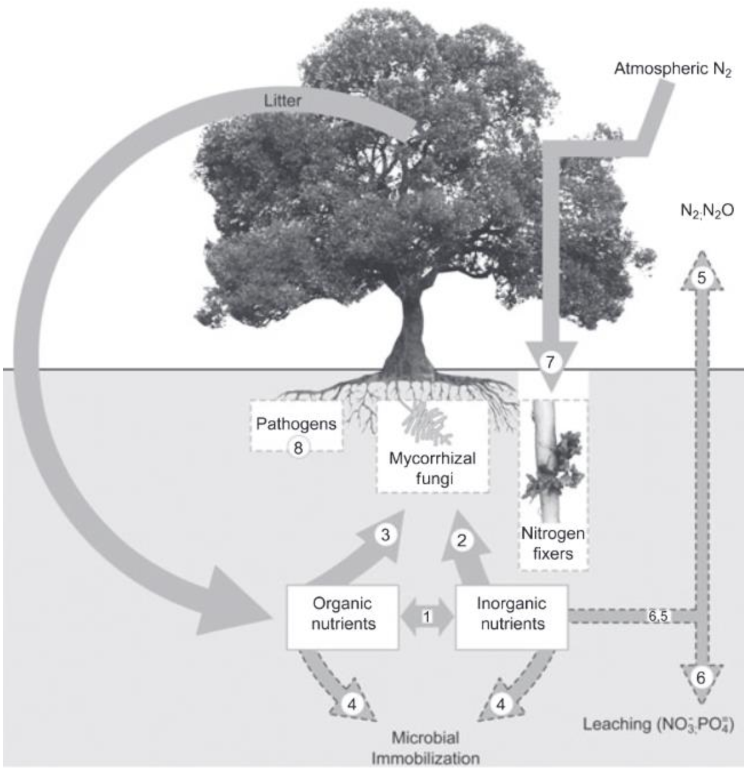

Figure 28 Soil microbial processes

The processes depicted in the model are not linear, immobilised microbial nitrogen can recycle back into bioavailable nitrogen, for instance when an organism dies and is re-assimilated (Daly et al., 2021). Moreover, plants are not passive players gathering up the leftovers of microbial mineralization; rather, through direct actions and by triggering microbes to act, plants can shape N cycling (Daly et al., 2021).

Soil organic matter (SOM) is primarily found in the forms of particulate (POM), mineral-associated (MAOM) and a small portion, 1-2%, of dissolved organic matter (DOM), that is soluble in water

(Cotrufo & Lavallee, 2022). 'Raw' OM (i.e. leaf litter) is depolymerised and solubilised into POM or DOM, of which smaller particles (monomers) become bioavailable via sorption and desorption (the binding to other molecules) (Daly et al., 2021). Some of those particles that bind to mineral complexes form MAOM, which is more stable and can persist in the soil for centuries to millennia. Recent discoveries have revealed that the mineral complexes impose constraints on microbial access to substrates and protect the organic matter from being mineralised (Daly et al., 2021). Mineral complexes inhibit the physical access or the microbial activity of decomposer enzymes, for example by hydrophobicity, soil acidity or sorption (Schmidt et al., 2011). Next to that, it has been shown that root-derived carbon is retained in soils more efficiently than above-ground inputs of leaves or needles (Schmidt et al., 2011).

In the more conventional chemical soil analysis, a very important measure of soil fertility is the Cation-Exchange Complex (CEC). The CEC is the capacity of the soil to hold on the negatively charged nutrients that plants need for their growth. Sandy soils rely on organic matter (OM) to hold on to these nutrients, therefore a low amount of organic matter, result in a low CEC. The Sum of Bases-S indicates how much of the CEC is taken up by useful cations and the saturation is the Sum / CEC potential.

Chemical analysis

Chemical soil analysis has been conducted at the start of the project in 2007 at 6 different locations. The same analysis has been performed in April 2024 to find out what the influence of the 15 years of agroecological management has been on the chemical parameters of the soil. Soil samples were collected at 0-10 cm depth, any vegetation and leaf litter was removed before sample was taken. The locations in which the samples were taken are described in more detail in appendix II.

The results from 2007 show very nutrient-poor conditions in almost all locations, except for sample 'Frente'. The soil is mainly made up off sand, has a low pH, low amounts of organic matter, resulting in a low CEC. Particularly, the availability of the nutrients Phosphor (P), Calcium (Ca) and Magnesium (Mg) were low at the different sample sites. The sample 'Frente', was taken at the front of the terrain, close the main road were a variety of trees had been growing for a longer time. The soil there contains more organic matter, 6.7% compared to 1-1.7%, resulting in a higher CEC, 8.8 cmolc/l compared to 2.4-3.5 cmolc/l. The soil of this sample has a higher ability to retain nutrients, and also has a slightly higher availability for the measured nutrients. However, most of the potential of the CEC of sample Frente is taken up by H + Al, probably due to the acidic soil conditions. The soil texture was characterized as class IV and to prevent soil erosion it was advised to adopt soil conservation practices and minimize the time in which the soil is without cover .

Interestingly, the measured parameters show improvement across all samples, even in the grass field. The grass sample is taken in a location north of the main house, about one-third of the way up the west facing slope, and is best compared to the sample 'Norte' of 2007. Compared to this sample the pH has risen into a normal range, P and Ca amounts are similar while K & Mg values have risen. The OM content is lower, about half, but interestingly, the CEC is higher, even though the clay content is similar. The saturation of bases is also higher.

Table 2 ***Chemical soil analysis.*** *Soil analysis was conducted at 6 different locations in 2007, and at 4 different locations in April 2024. Samples were collected at 0-10 cm depth. Full description of sample locations can be found in Appendix II.*

		2007						2024			
	Unit	**Norte**	**Sul**	**Morro**	**Baixa**	**Rancho**	**Frente**	**Old**	**New**	**Grass**	**Swamp**
Texture	% clay	13	12	14	13	14	14	16	9	14	14
pH		4.8	4.9	4.6	4.8	4.5	4.6	5.6	6.7	5.9	5.4
pH-SMP		6.8	7.0	6.8	6.9	6.7	5.6	6.6	7.0	7.0	6.2
Phosphor	ppm	8.3	5.1	3.1	3.4	2.4	3.2	15.8	25.8	5.7	9.0
Potassium	ppm	32	22	20	23	14	31	82.35	99.9	70.5	70.5
Organic matter	%	1.7	1.2	1.4	1.4	1	6.7	1.7	1.9	0.6	2.7
Aluminium	cmolc/l	0.4	0.4	0.7	0.7	0.8	1.4	0.0	0.0	0.0	0.0
Calcium	cmolc/l	1.1	1.8	0.4	0.5	0.5	1.1	3.4	3.4	1.5	2.6
Magnesium	cmolc/l	0.5	0.3	0.3	0.2	0.2	0.6	1.9	2.5	1.3	1.0
Sodium	ppm	26	9	28	21	21	32	-	-	-	-
H + Al	cmolc/l	1.74	1.38	1.74	1.55	1.95	6.9	2.2	1.3	1.4	3.4
Sum of bases-S	cmolc/l	1.80	1.20	0.88	0.85	0.83	1.92	5.44	6.06	2.89	3.76
CEC	cmolc/l	3.54	2.58	2.62	2.40	2.78	8.82	7.64	7.36	4.29	7.16
Saturation Bases-V	%	50.85	64.51	33.59	35.42	29.86	21.77	71.24	83.35	67.29	52.46

The samples from the new system, that has been implemented about 15 months prior, were taken close to grass samples, so would best be compared to the same 2007 reference. Compared to this reference, the texture is a bit sandier and the pH has risen notably, it is even a bit on the high side. OM content is slightly higher and the CEC has more than doubled, with 83% of it taken up by useful cations. Nutrient content values for P, K, Ca, and Mg are the highest measured across all samples.

The samples from the old system have been taken near the top of the east facing hill, north of the main house, and would be geographically closest to the sample 'Morro'. These sample from the old system is similar to the new system, however, the pH is lower and a larger part of the CEC is taken up by H + Al. This location is also not as high in nutrients as the new system, but a major improvement compared to the 2007 sample.

The sample from the swampy area is taken, more or less, at the same location as 'Rancho'. The sample has a lot higher OM content than before, highest of all 2024 samples, and also has quite a high CEC. The pH has improved, but is still quite low, and therefore, almost half the CEC is still taken up by H + Al, which is a considerable improvement compared to the 30% from 2007. Thus, nutrient concentrations for P, K, Ca and Mg are all about 4-5 times as high.

Overall, the soil quality of all locations, whether extensively managed, or left alone, has noticeably improved. The pH has risen, as has the CEC and its saturation, resulting in considerably higher nutrient concentrations. Of all the locations sampled in 2024, the soil of the new agroforestry system shows the best results, with a high pH, a high CEC with the best base saturation, and, therefore, the highest concentrations of available nutrients.

Interestingly, even the grass system that has essentially been robbed of nutrients, as organic matter has been removed and supplied to other areas, has improved in quality. This leads me to hypothesise that soil fungi have facilitated this improvement via the so called 'wood wide web'. Mycorrhizal fungi of different plants are connected underground and form common mycorrhizal networks, known as ‘The Wood Wide Web’ (Rhodes, 2017). These networks serve to transport water, carbon, phosphorus, nitrogen, compounds that serve to defend the plant against parasitic attack and allelopathic chemicals, that influence growth and survival of other plants, as well as signals, allowing underground communication between different plants. The change to agroecological management and planting of more trees around the grass field has probably allowed the belowground wood wide web to become strong and sufficiently supportive to supply this location with the measured nutrients.

A lot of OM has been added to the soils of the new and old system, however this is not reflected in the results as OM values are similar to the old samples. This could prove that most OM that is added is rather rapidly degraded and broken down and does not contribute much to the SOM. In the ‘swamp’ sample taken behind the rancho, the OM content is a lot higher, probably OM is not broken down as easily due to anaerobic conditions.

Pfeiffer chromatography

The Pfeiffer chromatography (PC) is a low-cost, relatively easy, holistic test for soil health (Rivera & Pinheiro, 2011). It takes all soil aspects, physical, chemical and biological into account and produces an image that can only be interpreted by considering the soil as a whole (Pilon et al., 2018). The PC was designed by Pfeiffer to analyse and distinguish the quality of soils, especially in biodynamic farming systems (Pfeiffer, 1984). I have used the adapted version from Riveira and Pinheiro (2011) as described in the “Guia practica de Cromatografia de Pfeiffer” (Pilon et al., 2018).

The soil is the queen of the chessboard, it is connected to all other organisms, plants, fungi, animals, and cannot be reduced to numbers, but must be interpreted as a whole. The PC is a holistic approach that interprets the soil as one living superorganism, therefore revealing its emergent properties, as the soil system is much more than solely its chemical components.

Soil samples were collected at the same four sites as for the chemical soil test: at the grass field, the new, and the old agroforest system and the swampy area, at two different horizons, the ‘top’ (0-3 cm) and ‘bottom’ (5-10 cm) layer. Samples have been dried in the shade for 7-10 days, grinded and sieved, after which 5g of soil is added to 50ml dispersant, sodium hydroxide (NaOH). After a stirring process the supernatant is taken up by a filter paper treated with the photoreactive $AgNO_3$ (see appendix IV, for more detailed methodology).

The sodium hydroxide, also known as caustic soda, is widely used in cleaning, because of its excellent ability to dissolve organic molecules. In the chromatography it dissolves the organic substances of the sample, it brings mobility by breaking down the rigid, solid substances into smaller molecules that can run through the paper (Bischof, 2017). The NaOH with sample runs through the sensitized filter paper, from the centre until the 6 cm mark. As soon as the sample runs on the silver film there is formation of silver hydroxide (AgOH), which quickly dissipates into silver oxide that reacts with light to form a dark colouration (Ag_2O)(Pfeiffer, 1984). The minerals, organic molecules, proteins, vitamins and humic substances in the sample react with silver, forming complexes that result in different colours, forms and secondary structures such as arrows, zones and circles (Bischof, 2017). The light reaction ends in 5 to 7 days, after which the chroma reveals the complex of colours and form.

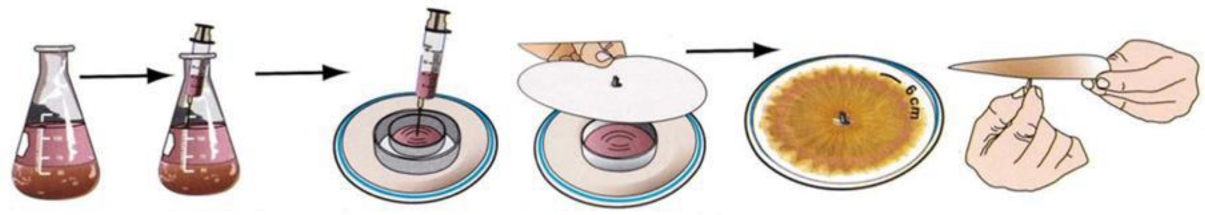

Figure 29 Methodological process. Soil is mixed with dispersant, supernatant is put in small dish to let filterpaper absorb fluid. Image from Rivera & Pinheira (2011).

The chroma is interpreted as a whole, making it difficult to say specific things about chemical composition or which minerals are lacking. The chroma is divided into zones for interpretation.

Zone 1: The central zone contains the heaviest materials, such as minerals and complexes, and is also referred to as aeration zone. Soil with little aeration and anaerobic metabolism have a dark inner zone, while aerobic soils show creamy yellow colouration. In soils with a high nitrogen concentration an amin silver complex $[Ag(NH_3)_2]+$ is formed, resulting in a white coloration in the central zone (Bischof, 2017).

Zone 2: The inner chemical zone is related to soil texture and clay properties. Concentric rings present in this zone indicate presence of soluble minerals, if these rings are detached they may indicate excess amounts of soluble minerals.

Zone 3: The middle zone contains the midweight materials, such as organic compounds, and the humus gives it a brown colouration. If the brown colouration is disconnected from the more inner zone, it indicates that the humus is immobilized.

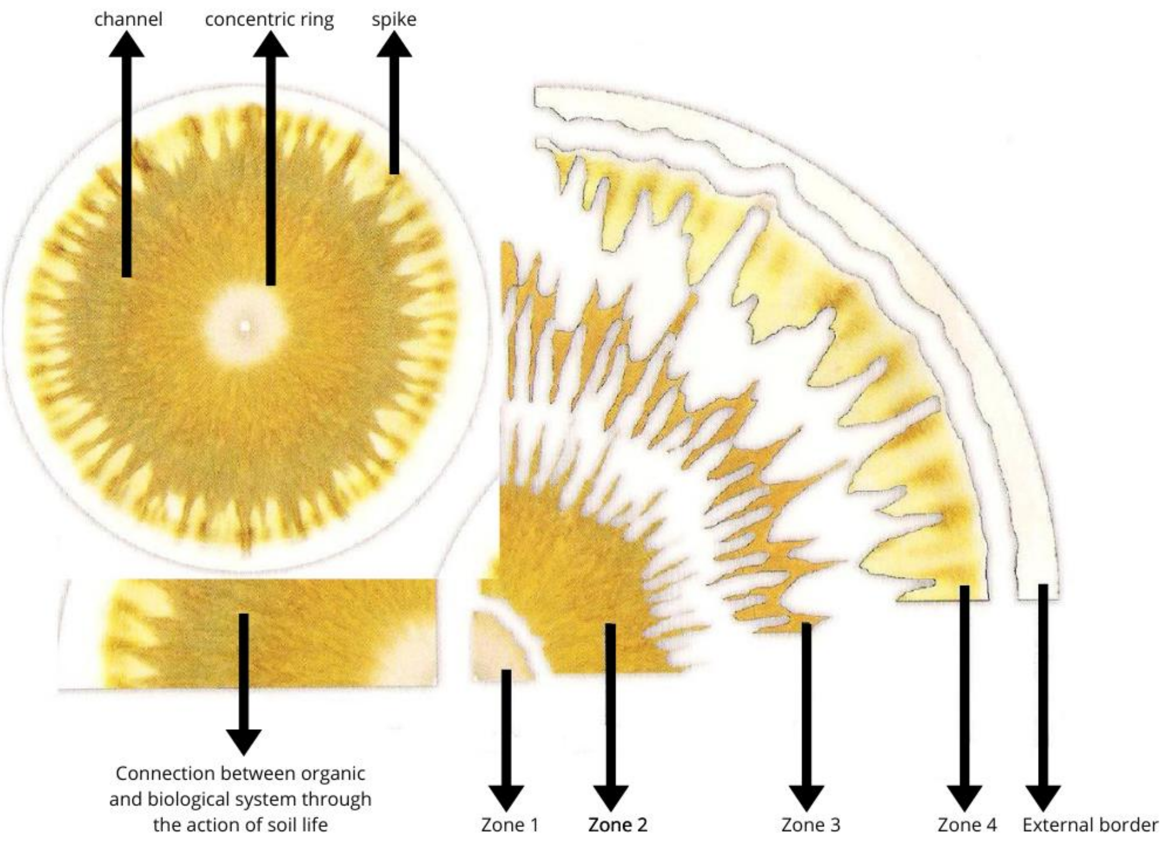

Figure 30 Interpretation of chroma. Image adapted from Pilon et al., 2018.

Zone 4: The outer zone displays the lightest materials, created by metabolism of bacteria, fungi, and larger fauna, and is indicative of the microbiological activity and biodiversity of the soil. The zone is associated with the presence of channels and spikes. The number, rhythmic form and distribution, of channels and spikes indicate the balance between the micro-organisms. Moreover, the channels are a pattern of integration between the different zones, healthy soils will express channels that start in the central zone and extend to the outer zone. Additionally it is mentioned that, when a chroma has more spikes it is made up of a larger variety of microbial materials (so larger diversity), and if a chroma has more channels, it is more nutritious.

As suggested in the *Guia practica* I used a healthy forest soil sample as a reference, collected from a nearby forest of a similar soil type, as well as a pure compost sample, as a nutrient-rich reference and a practically pure sand sample taken at 1m depth as a nutrient poor, unhealty reference (see fig below). Each of the chromas were analysed and given a score 1-5 on the integration, channels, spikes and colour, based on these references. Details on visual scoring of chromas are explained in appendix IV.

Figure 31 Pfeiffer chromatography samples used as references. Compost on the left as nutrient-rich, Forest top layer in the middle as healthy balanced reference and deep sand layer on the right as nutrient poor, unhealthy reference.

The differences between the two well-expressed, healthy samples on the left and the dull, unfertile sample on the right, is striking and quite intuitive. The two samples on the left are have a well aerated, nutrient-rich inner zone, with the compost inner zone being larger than the forest's. There are clear integration patterns between the zones, with channels stretching from the inner to the outer zone, opening in spikes, which are most obvious in the compost sample, and the colours are heterogenous and intense. The right sample on the other hand has a dark centre, homogenous colouration, without channels or spikes, making it impossible to identify zones.

All of the developed chromas of the soil samples are depicted in compressed form on the page below. With the chromas is a pictogram indicating their score, full analysis of chromas can be seen in appendix IV.

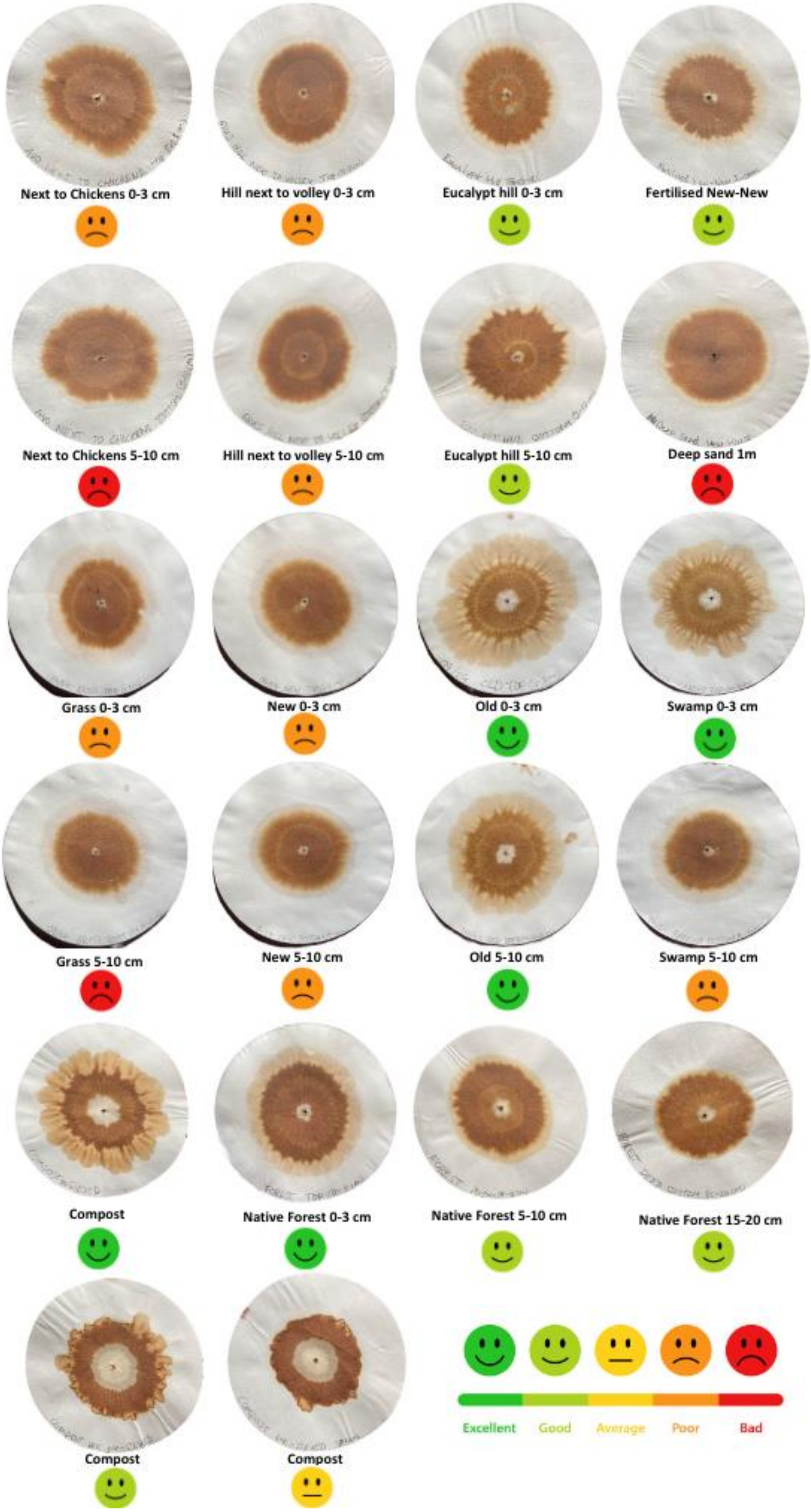

Figure 32 Pfeiffer chromatography results. Sample collection and analysis is described in more detail in appendix IV.

Apart from the references, the only soils samples that seem to be healthy, with a well-expressed chroma, are the old agroforest system, the swamp top layer, on top of the hill below Eucalyptus and the fertilised new-new system. What all of these locations have in common, is some larger trees that deposit abundant amounts of organic matter. The samples taken from the grass systems, the new agroforest system and next to the chicken run, below the avocado, are all quite dull, homogenous without good integration, and indicate that the soil there is not of high quality.

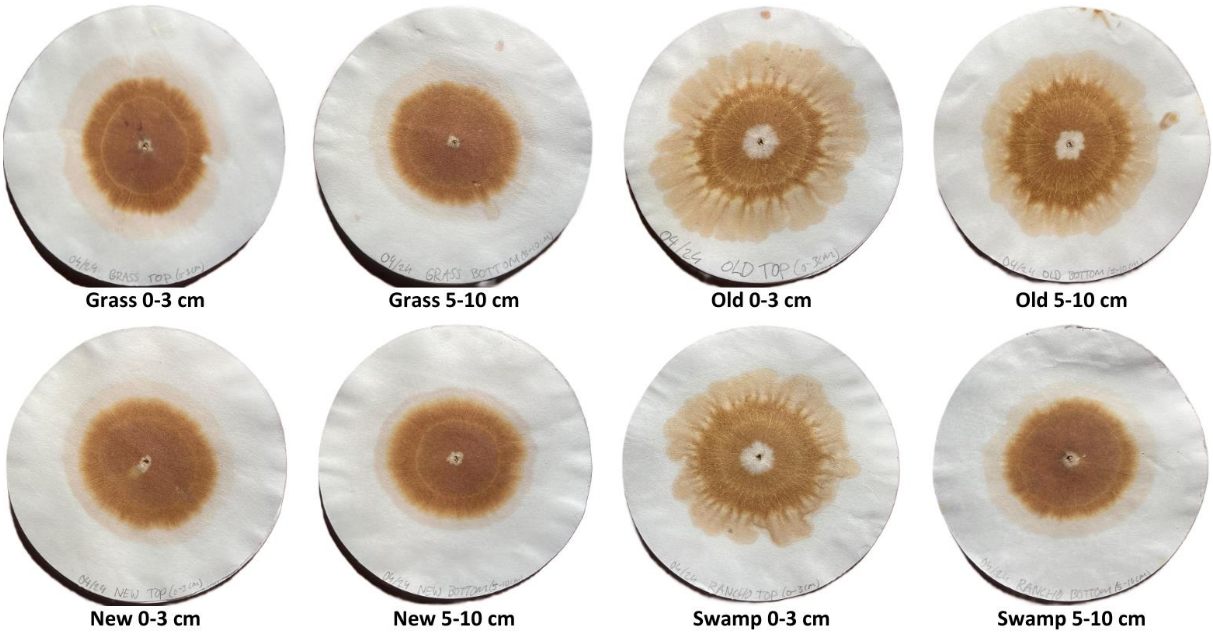

Figure 33 Pfeiffer chromatography results from grass field, new and old agroforestry system and swamp, taken at two different horizons (0-3 cm and 5-10 cm).

The chromas of the locations analysed using the chemical soil test are depicted above, and show quite different results than the conventional test. Only the chromas from the Old agroforestry system and the top layer of the swampy area are well developed. These show good integration between the different zones, have clear channels and spikes, indicating a diverse and balanced soil life. These three samples also have a larger, white central zone, indicating that they are richer in nitrogen.

The other five chromas look rather dull, without good integration and quite homogeneous expression of colours in each zone. Detached concentric rings are clearly visible, particularly in the grass top and new system bottom layer, possibly indicating excess of soluble minerals, but more likely indicating deficient integration between soil microbial, mineral and organic systems. The grass and new system top layers show some channels, but they are sparse, and quite weak, only present in the outer layer. The swampy deeper layer seems to have anaerobic metabolism, as the central chroma displays some dark colouration.

Overall, as expected beforehand, results of the chromatography indicate that the old agroforestry system and the top layer of the swampy area have the best soil quality. They have well developed and integrated chromas, indicating that the soil is biodiverse and has a good balance between mineral, humus and microbial parameters. The soils in the other locations are not so healthy and the chromas indicate that the soil has a lack of microbial activity.

Interestingly, according to the chemical soil analysis, the soil of the new agroforestry system should have the highest quality. It has a high pH, high CEC with the best saturation and the highest concentrations of nutrients. However, when looking at the chroma of the new system, it becomes clear that a picture might say more than a thousand numbers.

Pfeiffer chromatography is widely accepted as decent indicator of soil quality by the scientific community (Carneiro & Campos, 2021; Coaracy et al., 2019; de Melo et al., 2019; Pilon et al., 2018). A study in Italy that compares the chromatography to conventional chemical analyses, found a strong significant correlation between chromatography patterns and soil OM, total N and assimilable P and Br (Kokornaczyk et al., 2017). Kokornaczyk et al., conclude that chromatography may provide an overall and reliable view on the soil quality: *"strong radial differentiation and intense colouration of the patterns seem to be signs of good soil quality, whereas concentric pattern differentiation and blurred colours indicate an unfertile soil".*

The lack of a diverse micro-biotic community in the grass field and the new agroforestry system is most likely due to a lack of organic matter and humus, which provides food for these digesters. Currently, a lot of inputs are already supplied to improve the soil quality of the new system, the next section discusses those sources and suggests improvements.

External inputs

Initial decomposition rates of plant residues correlate with indices of their bulk chemical composition, such as the C/N-ratio (Schmidt et al., 2011). Fertiliser sources with low C/N ratio decompose quickly, rapidly making their nutrients bioavailable, while sources with a high C/N ratio take more time to break down, more effectively helping to build up SOM. In scientific literature is mentioned that C/N ratios above 15:1 typically induce temporary net N immobilization (Gilmour, 1998; Gloutney et al., 2022; Sullivan et al., 2002; Ye et al., 2018). To break down organic matter with high C/N ratios, micro-organisms require nitrogen, if this is unavailable, they forage their surrounding environment to meet their requirements. This can lead to temporary net immobilization of nitrogen in the soil, meaning that more nitrogen is tied up in microbial biomass and organic matter than is released in plant-available forms. As decomposition of the biomass progresses, nitrogen and other nutrients are released by the micro-organisms, but this might take some time.

I have compiled information about the nutrient contents of the organic fertiliser sources applied to the developing agroforestry systems. Most of the inputs are organic plant matter taken from another location on the land, essentially re-allocating nutrients from one place to another. A list of all the sources with their C/N ratios are collected in table 3 below.

Table 3 External inputs supplied to agroforestry system with corresponding Carbon / Nitrogen ratios.

Source		***C/N ratio***
Grass (*species dependent*)		20-40
Eucalypt (*E. robusta*)	Leaves	30
	Small branches (D <2.5 cm)	112
	Big branches (D >2.5 cm)	154
Margaridão (*T. diversifolia*)		25-47
Elefant grass (*P. purpureum*)		34
Compost dry toilet		27
Urine		0.7-0.9
Cow manure	Fresh	25
	Bio-fertiliser (digested)	19
Compost from food waste (input dependent)		15-20
Chicken manure		11

I. Dried Grass

Dried grass is primarily composed of carbon and generally has quite a high C/N content of 30-50, the exact composition depends on the species and its environment. A popular pasture species, *Cynondon sp.,* often found in tropical, poor and sandy coastal areas has been reported with an C/N content of 30, with 2% N in its leaves and 0.7-1% in the stems (Sollenberger, 2008; Velez-Santiago et al., 1979). It is argued that litter of C_4 grasses might aggravate existing nitrogen shortages in low-input systems, acting as a sink of available nitrogen. A study looking at effects of different C/N ratios on bacterial compositions and processes in an organically managed soil reported that the addition of straw (C/N 29) lowered the total inorganic nitrogen (Ye et al., 2018). They suggested that microorganisms use existing N resources in the soil for growth, enzyme production and subsequent decomposition of straw, as has previously been suggested in the literature.

Table 4 Nutrient content of the tropical grass of the Cynodon family

Cynodon sp.	**P %**	**K %**	**N %**	**C %**	**C/N**
Leaves	0.2	2.15	2.22	35	16
Branches	0.18	2.30	1.04	40	38

II. Wood

Wood has a very high C/N ratio, especially eucalyptus wood, as it is a fast-growing species, adapted to nutrient poor soils. Its stems have a C/N content of 154:1, the branches, with diameter smaller than 2.5 cm, 112:1, and the leaves 29:1 (Parrotta, 1999). A study looking into the effects of high C/N amendments, mixed *Miscanthus x giganteus* straw and willow (*Salix miyabeana)* chips (C/N of 228 and 135, respectively) into the soil of a lettuce field (Gloutney et al., 2022). They reported lower lettuce yield in both treatments (35% and 17%, respectively) and attributed this yield reduction to N and P depletion in the root zone of lettuce.

Table 5 Nutrient content of Eucalyptus robusta

Eucalypt	**P Mg/g**	**K Mg/g**	**Ca Mg/g**	**Mg Mg/g**	**N Mg/g**	**C Mg/g**	**C/N**
Leaves	0.615	6.08	11.7	2.30	15.1	444	29.4
Branch + stem <2.5 cm D	0.411	5.25	18.2	2.52	4.9	549	112
Branch + stem > 2.5 cm D	0.275	2.05	16.8	0.17	3.0	462	154

III. Mulch

Margaridão (*T. diversifolia)* has been praised as a soil fertility improver, due to its high biomass production with a relative high nutrient content, that quickly decomposes, quickly becoming bio-available (Jama et al., 2000; Radomski & BT de Oliveira, 2018). The high nutrient content has been credited to its ability to scavenge for nutrients in the soil using its proteoid root system. Biomass of *T. diversifolia* provides a range of macro- and micronutrients, improves soil structure and conserves moisture compared to inorganic fertilisers (Opala, 2020). However, the ability of an organic material to provide nutrients for crops and its ability to simultaneously increase the SOM are generally negatively correlated. Therefore, as margaridão decomposes quickly, it is reported to be good for short-term fertility, releasing essential nutrients, not effectively maintaining or helping to build up SOM (Opala, 2020).

The nutrient content of margaridão is highly variable, different studies report very different nutrient contents, which, therefore, seems to be quite environmentally dependent. In some studies, the nitrogen content of *T. diversifolia* is similar to that of legumes, which form symbiosis with nitrogen-fixing bacteria. Based on a recent study in Parana, the neighbouring state of Santa Catarina, nutrient contents are as follows (Radomski & BT de Oliveira, 2018).

Table 6 Nutrient content of T. diversifolia and C. purpureus

	P **g kg-1**	**K** **g kg-1**	**Ca** **g kg-1**	**Mg** **g kg-1**	**N** **%**	**C** **%**	**C/N**
Margaridão	1.62	5.57	5.35	3.18	0.94	44.32	47.31
Margaridão + P	2.02	4.24	4.05	2.85	0.98	44.68	45.54
Average	1.82	4.90	4.70	3.01	0.96	44.50	46.40
Africa review Margaridão	0.37 %	4.1%	0.6%	0.27%	3.5	45.50	13
Elephant grass	4.3	46.3	4.6	3.1	1.24	42.15	33.99

Elephant grass is also used as mulch but to a lesser extent, its use as organic fertiliser has also been studied and the nutrient contents are included in the table (Yagi et al., 2020). The exorbitant high potassium content is due to the location of the study, which has a very high K concentration.

IV. Human faeces

The fertiliser from the compostable toilet is a mix of faeces, urine, toilet paper and sawdust (from pine or eucalyptus), and has been left to compost for six months before handling. A study from Norway examined the nutrient contents and fertilizer potential of human excreta using different amendments (Kelova et al., 2021). In one treatment they used a similar approach as used at Morada Ekoa; they composted the wet faeces 2 : 1 sanitary pine bark for 6 months at 20 degrees, yielding a C/N ratio of 27.9. They reported that actively composting at 38 degrees resulted in the highest amounts of mineral N, and accordingly, the barley yields treated with those fertilisers showed 80-90% higher yield compared to control, whereas the fertiliser composted at lower temperatures only resulted in a 10-46% increase of crop yield.

It is important to note that the faeces and urine have quite different nutrient outputs, only 14% of total expelled nitrogen is voided through the faeces (1.8g/cap/day), the majority is excreted as urea in urine (10.7 g/cap/day; Rose et al., 2015). Nutrient contents of urine are reported at 14-18% N, 13% C, 3.7%P and 3.7%K (Rose et al., 2015). The composition of the faeces is much more variable and the fractions depend strongly on dietary intake, but it is stated that about 25% of faeces is solid, of which 25-54% is bacterial biomass (containing about 50% protein), 2-25% nitrogenous matter, 25% carbohydrate, and 2-15% undigested lipids.

Table 7 Nutrient content of human faeces, both 'raw' and composted in dry toilet

Human Excreta	**P g/kg**	**K g/kg**	**Ca g/kg**	**Mg g/kg**	**S g/kg**	**N g/kg**	**C g/kg**	**C/N**
Composted	10.1	9.2	20.0	4.7	3.5	16.7	466	27.9
Faeces	1.8-9.9	1.8-7.2	2.6-3.8	0.9-2.9	0.9-1.5	7	50	7.1
Urine	0.36-0.93	0.02-2.07	0.04-0.36	0.15	0.96-1.16	1.4-25 (7.86)	5.48	0.7

V. Biofertilizer

Biofertilizer is made by anaerobically digesting cow manure in water using a mix of micro-organisms. This diverse micro-biotic community digests most of the organic nutrients and converts some to inorganic compounds (Mukhuba et al., 2018). For example, the available nitrogen in the digester, whether from the substrate, atmosphere or from purging, is converted to ammonium and nitrates which remain in the digester until the end of the process. This is advantageous, because N mineralisation ensures that Nitrogen is available in a plant-accessible form. Multiple studies have reported higher ammonium content in digestate compared to fresh manure, providing evidence that it is a useful source to provide bio-available nutrients (Gómez-Brandón et al., 2016; Mukhuba et al., 2018). Moreover, the digestion process also resulted in reduction of heavy metal content, which is beneficial to the environment when the digestate is used as fertiliser instead of fresh manure.

Nutrient content of fresh and digested cow manure are depicted in table 8 below. The concentrations of inorganic phosphor and potassium are slightly lower in the digestate, as some of these nutrients are used by the micro-organisms.

Table 8 Nutrient content cow manure and biofertiliser

Cow manure	**P** ppm	**K** ppm	**NH_4** ppm	**C** %	**C/N**
Fresh	0.43	0.9	1.6	39.7	24.8
Anaerobically digested	0.26	0.56	1.91	36.76	19.2

VI. Organic food waste

Organic food waste is easily composted by micro-organisms and macro-fauna such as earthworms, and provides organic matter with a balanced C/N ratio. The exact ratio depends strongly on the composition of the food waste, but is generally between 15-20:1 (Sullivan et al., 2002). One study looking at the effect of bulking agents created two compost mixtures, FYP (food + yard trimmings + paper, respectively 33 + 11 + 7 g N kg^{-1}) and FW (food + wood waste + sawdust, respectively 33 + 1 g N kg^{-1}), composted via a modification of the aerated static pile method (Sullivan et al., 2002). They reported the following nutrient compositions in the composts:

Table 9 Nutrient composition of composted food waste in two treatments. FYP, food waste, yard trimmings and paper, and FW, food waste + wood waste + sawdust. 9

Compost method	P g/kg	K g/kg	Ca g/kg	S g/kg	N g/kg	NH_4 Mg/kg	NO_3-N Mg/kg	C g/kg	C/N
FYP	2.6	10	22	2.7	11.7	28	68	232*	20*
FW	2.7	11	28	2.9	12.0	20	349	232*	20*

*Approximate values, C has not been measured but they use the typical C content found in soil organic matter, multiplied by the volatile solids (concentration of OM compost), to get a measure for the carbon content of the compost and an approximate C/N ratio.

VII. Chicken manure

Chicken manure and poultry bedding is processed into small pellets and is comprised of: 2% N, 3.4% P_2O_5, 2.5% K_2O, and 22% organic carbon. All of the nutrients are inorganic and available for uptake by living organisms.

Table 10 Nutrient composition of processed chicken manure

	P %	K %	N %	C %	C/N
Chicken manure	3.4	2.5	2	22	11

VIII. Calcium Carbonate ($CaCO_3$)

Calcium (Ca) is a macronutrient that plants need in relatively large quantities, by adding calcium carbonate, a sufficient amount of Ca is guaranteed. When the new system was initiated, three sources of calcium where added: Stone flour (from marble), lime powder, and ground mussel shells. Calcium Carbonate ($CaCO_3$) can help neutralize acidic soils, by reacting with hydrogen into free Ca-ions, water and carbon dioxide ($CaCO_3+2H^+ \rightarrow Ca^{2+}+H_2O+CO_2$). All of the sources (marble, lime and shells) consist almost solely of $CaCO_3$, so it is of little use to add all three sources. Adding to much might disrupt the soil microbial community, lead to nutrient imbalance, or even create alkaline conditions. The stone flour or lime powder from marble might possibly also contain trace elements of Mg, Fe, Mn, Zn, and Cu. Marble is a metamorphic form of limestone, but in a recrystallized form.

Soil advice

First of all, you are clearly doing something right. The management practices are improving the soil quality, demonstrated with results from both the chemical soil test, where all values have significantly improved, and in the Pfeiffer soil test, where the sample from the old system shows a diverse, healthy soil image. Therefore, the main advice is to keep doing what you are doing, as it is clearly working.

Based on the results from the chemical soil tests, the two agroforestry systems do not seem to have a shortage of nutrients. The grass field and swamp have low amounts of nutrients and are posing limitations for plant growth.

The Pfeiffer chromatography results demonstrate that the soil on the top of the hill, next to the eucalyptus trees already have a better organic zone, which is well-connected to a diverse microbial community. The fertilised new lines of agroforest, which are practically in the same location, don't look as good as those samples. Hand-ploughing the top layer of soil and mixing it with fertiliser and organic matter, seems to have had quite some effect on the microbial community in the soil. In the chroma 'fertilised new-new' the effect of this soil addition can clearly be seen, as the chemical zone is a lot larger and a concentric ring is apparent, separating the chemical from the organic zone. This effect should be quite temporary, I would expect the microbial community to have adapted to new conditions after at least months. It would be interesting to study how quickly the soil ecosystem recovers from such a disturbance. You could take a soil sample every month or 2 months to see how the conditions in this new agroforest field develop. Next to that, as current conditions seem quite good at the top of the hill next to the eucalyptus, I would advise to plant some more native, food producing trees along this edge, they might need less initial help and could replace the eucalyptus over time.

What the locations with healthy looking soil chromas all have in common is abundant amounts of organic matter and a diverse decomposing microbial community. One idea to help kickstart new locations of agroforest, besides supplying fertiliser and organic matter, would be to add some micro-organisms from other locations, such as a natural forest, compost, or older sections of agroforest. For each line of agroforest, you could spread one bucket of top soil and one bucket of leaf litter from one of these healthy locations to supply a diverse microbial community to your developing system.

Moreover, from the chromatography results it becomes clear that many locations on the land are not yet meeting minimal standards, even the new agroforestry system that receives a lot of inputs. My advice would be to keep adding abundant amounts of organic matter, and try out the above, to see if this helps to somewhat speed up the process of building up a healthy soil.

I will sum up the external inputs in order from fastest bio-available nutrients, to slow-decaying matter that contributes more to SOM. For a quick release of nutrients it is best to use bio-fertiliser, urine and chicken manure. For a medium release the dry toilet compost, food waste and mulch from margaridão (or other plant leaves) can be useful. The slowest release of nutrients comes from the dried grass, eucalyptus leaves and wood, and brings the risk of temporarily using up N for the soil environment.

I would, therefore, advice to fertilise with biofertilizer, urine, chicken manure or compost when high C/N ratio organic matter is supplied to non-leguminous, fast-growing crops, such as corn, lettuce or broccoli. These crops do not have N-fixing bacteria and a limited root system, and as they grow rapidly in a short amount of time, they might suffer from a temporary N shortage. I think it should be less of a problem for trees, as they have profounder connections in the soil system and more time to grow to maturity.

Another solution to overcome potential N immobilization is to intercrop densely with plants from the fabaceae, as this family has symbiotic relationships with N-fixers they could ensure sufficient soil N. These species are already used as natural nitrogen fixers across the land, but it might be useful the take possible N shortages into account when spreading high C/N organic matter and to intercrop with different beans more densely.

Biochar and organic fertiliser are widely used and proven to maintain crop production and sustainable development of agroecosystems. An 8-year study from Hu, et al., showed a significant positive impact of biochar and organic fertiliser on soil functional microbiomes and ecosystem multifunctionality, compared to single-chemical fertilisation (Hu et al., 2024). There are multiple pathways through which biochar helps amend soil functionality. First of all, it regulates soil microbial activities and metabolisms, which leads to improve soil nutrient availability, which in turn stimulates plant growth, changes root structure, and increases photosynthesis, thereby improving plant nutrient uptake, biomass, and yield (Hu et al., 2024). Moreover, biochar and organic fertilizer inputs can reduce nutrient losses by adsorbing nutrients from the soil and improving soil water holding capacity, further improving nutrient uptake by plants. Meanwhile, biochar can slow down the decomposition of organic fertilizers, the combination of biochar and organic fertiliser maintains the most ideal nutrient balance. All in all, biochar shows some promising results as valuable amendment for enhancing soil quality and improving crop yields. It would be interesting to try out biochar at Morada Ekoa, since the soils are so poor and sandy, adding a stable form of organic matter, such as biochar, would help retain water and nutrients, and consequently improve plant growth and yield.

The compost from the compostable toilet yields the best nutrient contents and fertilizer potential at higher temperatures. The composting chambers are already facing south, but it could be interesting to look at options to heat these areas even more, for instance, tubes with hot water from the solar heating system or a reflective system catching even more sunlight. Moreover, it might be interesting to separate faecal mass from the urine, since these two sources have such different nutrient compositions you might want to use them for different purposes.

Lastly, I think you do not need to use 3 different sources of Calcium Carbonate. In the creation of new lines of agroforest, both lime powder, ground marble and ground mussel shells were added, since they all consist almost solely out of $CaCO_3$ they all serve the same function. In the chemical soil results the calcium concentration seems sufficient, as does the pH, therefore I would argue that it is currently not needed to supply a lot of $CaCO_3$.

Ecosystem services

Morada Ekoa generates substantial ecological value by practicing its philosophy of living in harmony with nature. By creating conditions conducive to life, Morada Ekoa creates an environment where nature can thrive, thus allowing nature to provide a myriad of ecosystem services that benefit everyone. All one has to do is provide the minimum requirements for nature to thrive and life will reciprocate with benefits of boundless value.

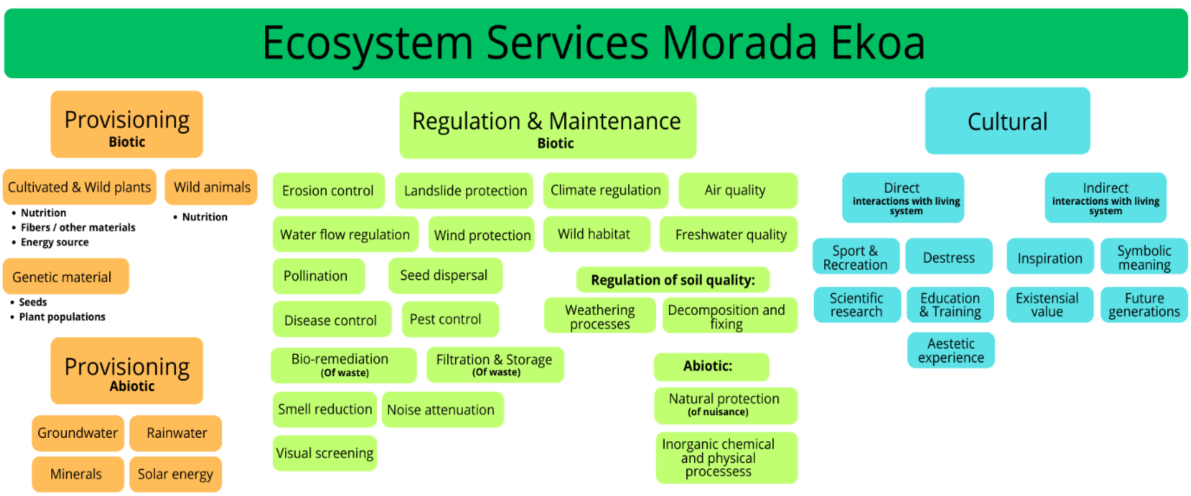

Figure 34 Ecosystem services of Morada Ekoa, mapped using the CICES framework

Conclusion

All in all, Morada Ekoa has transformed the land from monocultural cropland to a thriving permaculture institute, according to its central ethics *earthcare*, *peoplecare* and *fair share*. By creating conditions conducive to life, nature is empowered to create abundance and give back boundless benefits, referred to as ecosystem services.

Morada Ekoa generates economic, social and ecological value. Economic value is created though three primary streams: 50% ecotourism, 25% education and 25% food production. Social capital is cultivated as Morada Ekoa serves as an example and shows alternative ways of living; the reconnection of people and planet in a permaculture community creates a sense of belonging, improves cooperation, and ultimately well-being. Ecological value is enhanced by (1) accelerating natural soil-building processes to create a healthy functioning soil system capable of supporting a biodiverse agroecosystem, and (2) planting a wide variety of plants species. This increases habitat complexity and niche availability, thereby resulting in a biodiverse and redundant agroecosystem.

At Morada Ekoa there is no shortage of creative ideas or ambition to improve and expand. Time and money, however, pose limitations on the possibilities. Many great ideas have been suggested during my stay, but not all are feasible. The most important aspects are *Timing* and *Focus,* use them wisely and the sky is the limit.

Recommendations

- To produce food surplus, plant more agroforest, there is plenty of space.
- To be more self-sufficient, plant more staple foods, such as mandioca (cassava).
- To efficiently earn money from food production, focus on cash crops (high $R/kg).
- To achieve ambitious goals, such as opening a café, seek partnerships.
- To secure a sponsor and attract sufficient participants for courses, or to draft a grant proposal for a school project, begin early and plan meticulously; dedicate specific times each week to accomplish defined tasks.
- To ensure habitat for nature and minimise management efforts, keep tight management on exotic species, take it out root and all once they no longer serve their purpose.
- To improve biodiversity, provide nesting locations for birds, bats and insects.
- To use the landscape to your advantage, plant on top of the hill where organic matter has already improved soil quality.
- To improve the functioning of the soil system, keep providing abundant organic matter to developing systems
- To provide a kickstart of microbial diversity to a developing soil system, add one bucket of leaf litter and one bucket of top soil from a healthy soil system per newly planted line.
- To make sure your system has sufficient amounts of nutrients, take possible N-immobilisation into account when supplying high C/N organic matter to fast-growing annual crops.
- To improve the functioning of the soil system, try out biochar as soil amendment to improve soil organic matter

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Appendices

Appendix I

Total harvest (kg) and value ($R) of all the food collected at Morada Ekoa in 2 months (April 9 - June 9, 2024).

Common name	Total harvest (kg)	Market value ($R)	Organic value ($R)
Acerola	0.960	34.56	34.56
Avocado	71.003	284.01	553.82
Banana	14.400	72.00	66.24
Basil	0.015	2.25	2.40
Bell Pepper	0.015	0.12	0.26
Big Red Pepper	0.045	0.67	0.76
Brazilian Grape Tree	0.060	2.40	2.40
Cassave	31.850	159.25	296.21
Cherry of the Rio Grande	0.425	17.00	17.00
Corn	0.250	0.00	0.00
Curcuma	0.250	15.00	15.00
Ginger	0.050	0.65	1.00
Guave	3.800	26.60	62.70
Jelly Palm	0.412	7.83	7.42
Kidney Bean (Red/White)	0.050	0.00	0.00
Lettuce	0.200	0.00	0.54
Lime	1.000	4.00	6.50
Macadamia Nut	0.010	1.20	1.20
Money Tree	0.280	14.00	14.00
Mulberry	0.005	0.15	0.15
Ora-Pro-Nobis	0.820	65.60	65.60
Orange	66.050	330.25	462.35
Oregano	0.026	3.90	4.16
Papaya	2.900	23.20	24.65
Passion Fruit	5.700	57.00	57.00
Peanut	1.795	17.95	21.54
Pigeon Pea	0.400	3.20	4.00
Pineapple	0.800	6.00	12.90
Pumpkin	3.040	9.12	13.07
Queen Palm	1.000	20.00	20.00
Rangpur	26.550	106.20	172.57
Raspberry	0.075	3.00	4.50
Small Red Pepper	0.002	0.03	0.03
Sugar Apple	11.700	292.50	351.00
Sugar Cane	3.800	0.57	0.57
Tangerina	8.900	35.60	57.85
Thyme	0.001	0.15	0.16
Wild Sage	0.015	0.30	0.30
Total	258.654	1616.26	2354.41

Appendix II

Species list of all human-planted and/or managed plant species of Morada Ekoa. The list is ordered alphabetically on taxonomic order, family and species. English and Brazilian common names are included. A tick and cross symbol are used to indicate its native range, to Brazil and to the literal Atlantic forest of Santa Catarina. Species main function(s) are also described.

Order	Family	Scientific name	Common name	Brazilian name	Native to Brazil	Locally native	Function
Alismatales	Araceae	*Anthurium Sp.*	Anthurium	Anthurio	✗	✗	ornamental
Alismatales	Araceae	*Colocasia Esculenta*	Taro	Taro	✗	✗	food
Alismatales	Araceae	*Monstera Deliciosa*	Swiss Cheese Plant	Costela-De-Adão	✗	✗	ornamental / food
Alismatales	Araceae	*Thaumatophyllum Bipinnatifidum*	Split-Leaf Philodendron	Imbê	✓	✓	ornamental / food
Apiales	Apiaceae	*Coriandrum Sativum*	Cilantro	Salso	✗	✗	aromatic
Apiales	Apiaceae	*Daucus Carota*	Carrot	Cenoura	✗	✗	food
Araucariales	Araucariaceae	*Araucaria Angustifolia*	Brazilian Pine	Araucária	✓	✓	food
Arecales	Arecaceae	*Archontophoenix Cunninghamiana*	Bangalow Palm	Palmeira Real	✗	✗	ornamental
Arecales	Arecaceae	*Bactris Gasipaes*	Peach Palm	Pupunheira	✓	✗	food
Arecales	Arecaceae	*Butia Catarinensis*	Jelly Palm	Palmeira Butia	✓	✓	food
Arecales	Arecaceae	*Cocos Nucifera*	Coconut Tree	Coqueiro	✗	✗	food
Arecales	Arecaceae	*Euterpe Edulis*	Jussara Palm	Jusare	✓	✓	food

Order	Family	Scientific name	Common name	Brazilian name	Native to Brazil	Locally native	Function
Arecales	Arecaceae	*Syagrus Romanzoffiana*	Queen Palm	Jériva	✓	✓	food
Asparagales	Asparagaceae	*Dracaena Trifasciata*	Snake Plant	Espada-De-São-Jorge	✗	✗	ornamental
Asparagales	Asphodelaceae	*Aloe Vera*	Aloe Vera	Babosa	✗	✗	medicinal
Asterales	Asteraceae	*Baccharis Dracunculifolia*	Baccharis Dracunculifolia	Vassoura	✓	✓	pioneer/ ecological / propolis
Asterales	Asteraceae	*Baccharis Trimera*	Baccharis Trimera	Carqueja	✓	✓	medicinal
Asterales	Asteraceae	*Bidens Pilosa*	Black-Jack	Picão	✓	✓	food / medicinal
Asterales	Asteraceae	*Lactuca Sativa*	Lettuce	Alface	✗	✗	food
Asterales	Asteraceae	*Matricaria Recutita*	Camomile	Camomila	✗	✗	medicinal
Asterales	Asteraceae	*Sochus Oleraceus*	Sow Thistle	Serralha	✗	✗	food
Asterales	Asteraceae	*Taraxacum Officinale*	Dandelion	Dente-De-Leao	✗	✗	food
Asterales	Asteraceae	*Tithonia Diversifolia*	Mexican Sunflower	Margaridão	✗	✗	biomass
Boraginales	Boraginaceae	*Cordia Verbenacea*	Wild Sage	Erva Baleeira	✓	✓	aromatic / medicinal
Brassicales	Brassicaceae	*Brassica Oleracea*	Cauliflower	Couve-Flor	✗	✗	food
Brassicales	Brassicaceae	*Brassica Oleracea Var. Italica*	Broccoli	Brócolis	✗	✗	food
Brassicales	Brassicaceae	*Raphanus Sativus*	Radish	Rabanete	✗	✗	food

Order	Family	Scientific name	Common name	Brazilian name	Native to Brazil	Locally native	Function
Brassicales	Caricaceae	*Carica Papaya*	Papaya	Mamão	❌	❌	food
Caryophyllales	Amaranthaceae	*Beta Vulgaris*	Beetroot	Beterraba	❌	❌	food
Caryophyllales	Amaranthaceae	*Dysphania Ambrosioides*	Jesuit's Tea	Erva-De-Santa-Maria	✅	✅	aromatic / medicinal
Caryophyllales	Amaranthaceae	*Pfaffia Glomerata*	Pfaffia	Pfaffia	✅	❌	medicinal
Caryophyllales	Cactaceae	*Opuntia Ficus-Indica*	Prickly Pear	Palma Cacto	❌	❌	bioconstruction / food
Caryophyllales	Cactaceae	*Pereskia Aculeata*	Ora-Pro-Nobis	Ora-Pro-Nóbis	✅	✅	food
Caryophyllales	Cactaceae	*Selenicereus Sp?*	Dragonfruit	Pitaia	❌	❌	food
Caryophyllales	Nyctaginaceae	*Bougainvillea Sp.*	Bougainvillea	Era Primavera	✅	❌	ornamental
Caryophyllales	Nyctaginaceae	*Guapira Opposita*	Guapira Opposita	Maria-Mole	✅	✅	ecological / ornamental
Cornales	Hydrangeaceae	*Hydrangea Sp.*	Hortensia	Hortensia	❌	❌	ornamental
Cucurbitales	Cucurbitaceae	*Cucumis Sativus*	Cucumber	Pepino	❌	❌	food
Cucurbitales	Cucurbitaceae	*Citrullus Lanatus*	Watermelon	Melão	❌	❌	food
Cucurbitales	Cucurbitaceae	*Cucurbita Pepo*	Zucchini	Abobirnha	❌	❌	food
Cucurbitales	Cucurbitaceae	*Cucurbita Sp.*	Pumpkin	Abóbora	❌	❌	food
Fabales	Fabaceae	*Arachis Hypogaea*	Peanut	Amendoim	✅	✅	food
Fabales	Fabaceae	*Bauhinia Forficata*	Brazilian Orchid Tree	Pata De Vaca	✅	✅	pioneer / ornamental
Fabales	Fabaceae	*Cajanus Cajan*	Pigeon Pea	Feijão Gandu	❌	❌	biomass / food

Order	Family	Scientific name	Common name	Brazilian name	Native to Brazil	Locally native	Function
Fabales	Fabaceae	*Canavalia Ensiformis*	Jack Bean	Feijão-De-Porco	❌	❌	biomass
Fabales	Fabaceae	*Enterolobium Contorstisiliquum*	Pacara Earpod Tree	Timboúva	✅	✅	timber
Fabales	Fabaceae	*Inga Edulis*	Ice-Cream Bean	Inga Cipó	✅	❌	food
Fabales	Fabaceae	*Inga Sp.*	Inga	Inga	✅	❌	biomass
Fabales	Fabaceae	*Paubrasilia Echinata*	Brazilwood	Pau-Brasil	✅	❌	timber
Fabales	Fabaceae	*Peltophorum Dubium*	Peltophorum Dubium	Canafístula	✅	✅	timber
Fabales	Fabaceae	*Phaseolus Vulgaris*	Green Bean	Feijão Verde	❌	❌	food
Fabales	Fabaceae	*Phaseolus Vulgaris*	Kidney Bean (Red/White)	Feijão Magico	❌	❌	food
Fabales	Fabaceae	*Phaseolus Vulgaris*	Black Bean	Feijão Preto	❌	❌	food
Fabales	Fabaceae	*Schizolobium Parahyba*	Brazilian Fire Tree	Garapuvu	✅	✅	pioneer / ornamental
Fagales	Juglandaceae	*Carya Illinoinensis*	Pecan Nut	Noz Pecan	❌	❌	food
Gentianales	Apocynaceae	*Plumeria Rubra*	Frangipani	Jasmin Manga	❌	❌	ornamental
Gentianales	Rubiaceae	*Coffea Spp.*	Coffee Plant	Café	❌	❌	aromatic
Lamiales	Acanthaceae	*Thunbergia Grandiflora*	Blue Skyflower	Thunbergia	❌	❌	ornamental
Lamiales	Bignoniaceae	*Handroanthus Impetiginosus*	Pink Ipê	Ipé Roxo	✅	✅	ornamental / medicinal

Order	Family	Scientific name	Common name	Brazilian name	Native to Brazil	Locally native	Function
Lamiales	Bignoniaceae	*Handroanthus Serratifolius*	Yellow Ipe	Ipé Amarello	☑	☑	ornamental / medicinal
Lamiales	Lamiaceae	*Coleus Barbatus*	Coleus Barbatus	Boldo Brasileiro	✗	✗	medicinal / toiletpaper
Lamiales	Lamiaceae	*Coleus Comosus*	Coleus Comosus	Boldinho	✗	✗	medicinal / ornamental
Lamiales	Lamiaceae	*Cunila Microcephala*	Poejo	Poejo	☑	☑	aromatic / medicinal
Lamiales	Lamiaceae	*Ocimum Basilicum*	Basil	Majericão	✗	✗	aromatic
Lamiales	Lamiaceae	*Origanum Vulgare*	Oregano	Orégano	✗	✗	aromatic
Lamiales	Lamiaceae	*Salvia Rosmarinus*	Rosemary	Alecrim	✗	✗	aromatic
Lamiales	Lamiaceae	*Tetradenia Riparia*	Incense Bush	Mirra	✗	✗	medicinal / ornamental
Lamiales	Lamiaceae	*Thymus Vulgaris*	Thyme	Tomilho	✗	✗	aromatic
Lamiales	Oleaceae	*Tabernaemontana Catharinensis*	Jasmine	Jasmin Catavento	☑	☑	ornamental / medicinal
Lamiales	Verbenaceae	*Aloysia Citrodora*	Lemon Verbena	Lúcia-Lima	☑	☑	aromatic
Laurales	Lauraceae	*Laurus Nobilis*	Bay Leaf	Loureiro	✗	✗	aromatic
Laurales	Lauraceae	*Persea Americana*	Avocado	Abacate	✗	✗	food
Magnoliales	Annonaceae	*Annona ×atemoya*	Atemoya	Atemoya	☑	✗	food
Magnoliales	Annonaceae	*Annona Muricata*	Soursop	Graviola	☑	✗	food

Order	Family	Scientific name	Common name	Brazilian name	Native to Brazil	Locally native	Function
Magnoliales	Annonaceae	*Annona Squamosa*	Sugar Apple	Nona	✅	❌	food
Malpighiales	Calophyllaceae	*Calophyllum Brasiliense*	Guanandi	Guanandi	✅	✅	timber
Malpighiales	Clusiaceae	*Garcinia Gardneriana*	Bacupari	Bacupari	✅	❌	food
Malpighiales	Euphorbiaceae	*Manihot Esculenta*	Cassave	Mandioca	✅	✅	food
Malpighiales	Malpighiaceae	*Malphigia Emarginata*	Acerola	Acerola	✅	✅	food
Malpighiales	Passifloraceae	*Passiflora Edulis*	Passion Fruit	Maracuja	✅	✅	food
Malvales	Malvaceae	*Ceiba Speciosa*	Floss Silk Tree	Paineira	✅	✅	cotton, timber, oil
Malvales	Malvaceae	*Hibiscus Sp.*	Red Hibiscus	Hibiscus Vermelho	❌	❌	ornamental
Malvales	Malvaceae	*Hibiscus Sp.*	Yellow Hibiscus	Hibiscus Amerelo	❌	❌	ornamental
Malvales	Malvaceae	*Pachira Aquatica*	Money Tree	Castanheiro-Do-Maranhão	✅	❌	food
Malvales	Malvaceae	*Theobroma Cacao*	Cacao	Cacaueiro	✅	❌	food / aromatic
Myrtales	Myrtaceae	*Campomanesia Xanthocarpa*	Gabiroba	Gabiroba	✅	✅	food
Myrtales	Myrtaceae	*Corymbia Citriodora*	Lemon-Scented Gum	Eucalypto Cidró	❌	❌	aromatic
Myrtales	Myrtaceae	*Eucalyptus Robusta*	Swamp Mahogany	Eucalypto	❌	❌	biomass

Order	Family	Scientific name	Common name	Brazilian name	Native to Brazil	Locally native	Function
Myrtales	Myrtaceae	*Eugenia Brasiliensis*	Brazil Cherry	Grumixameira	☑	☑	food
Myrtales	Myrtaceae	*Eugenia Involucrata*	Cherry of the Rio Grande	Cereja-Do-Rio-Grande	☑	☑	food
Myrtales	Myrtaceae	*Eugenia Uniflora*	Pitanga	Pitangueira	☑	☑	food
Myrtales	Myrtaceae	*Myrcianthe Pungens*	Guabiyu	Guabijú	☑	☑	food
Myrtales	Myrtaceae	*Myrciaria Tenella*	Cambuí	Cambuí	☑	☑	food
Myrtales	Myrtaceae	*Myrciaria Trunciflora*	Brazilian Yellow Grape Tree	Jabuticabeira Amarela	☑	☑	food
Myrtales	Myrtaceae	*Plinia Cauliflora*	Brazilian Purple Grape Tree	Jabuticabeira Roxa	☑	☑	food
Myrtales	Myrtaceae	*Psidium Cattleyanum*	Strawberry Guave	Araçá	☑	☑	food
Myrtales	Myrtaceae	*Psidium Guajava*	Guave	Goiabeira	☑	☑	food
Poales	Bromeliaceae	*Ananas Comosus*	Pineapple	Abacaxi	☑	☑	food
Poales	Poaceae	*Bambusa Tuldoides*	Bamboo Tuldoides	Bambu	✗	✗	timber
Poales	Poaceae	*Cymbopogon Citratus*	Lemongrass	Capim-Limão	✗	✗	aromatic
Poales	Poaceae	*Cyperus Haspan*	Dwarf Papyrus Sedge	Tiririca	✗	✗	ornamental
Poales	Poaceae	*Cyperus Sp.*	Papyrus Sedge	Papiro	✗	✗	ornamental
Poales	Poaceae	*Dendrocalamus Asper*	Giant Bamboo	Bambuu Asper	✗	✗	timber

Order	Family	Scientific name	Common name	Brazilian name	Native to Brazil	Locally native	Function
Poales	Poaceae	*Guadua Chacoensis*	Guadua Bamboo	Bamboo Guadua (Nativa)	☑	✗	timber
Poales	Poaceae	*Megathyrsus Maximus*	Guinea Grass	Capim-Mombaça	✗	✗	biomass
Poales	Poaceae	*Pennisetum Purpureum*	Elephant Grass	Capim-Elefante	✗	✗	biomass
Poales	Poaceae	*Saccharum Officinarum*	Sugar Cane	Cana De Açúcar	✗	✗	food
Poales	Poaceae	*Zea Mays*	Corn	Milho	✗	✗	food
Proteales	Proteaceae	*Macadamia Integrifolia*	Macadamia Nut	Macadamia	✗	✗	food
Rosales	Cannabaceae	*Cannabis Sativa*	Cannabis	Canabis	✗	✗	medicinal
Rosales	Cannabaceae	*Trema Micrantha*	Jamaican Nettletree	Grandiúva	☑	☑	ecological
Rosales	Moraceae	*Artocarpus Heterophyllus*	Jackfruit	Jaca	✗	✗	food
Rosales	Moraceae	*Ficus Carica*	Fig Tree	Figueira-Commun	✗	✗	food
Rosales	Moraceae	*Maclura Tinctoria*	Old Fustic	Taiuva	☑	✗	food
Rosales	Moraceae	*Morus Nigra*	Mulberry	Amora Preto Arvore	✗	✗	food
Rosales	Rhamnaceae	*Hovenia Dulcis*	Japanese Raisin Tree	Uva-Do-Japão	✗	✗	food
Rosales	Rosaceae	*Fragaria × Ananassa*	Strawberry	Morango	✗	✗	food

Order	Family	Scientific name	Common name	Brazilian name	Native to Brazil	Locally native	Function
Rosales	Rosaceae	*Malus X Domestica*	Apple	Maca Julieta	✗	✗	food
Rosales	Rosaceae	*Pyrus Communis L*	Pear	Pera D'agua	✗	✗	food
Rosales	Rosaceae	*Rubus Sp.*	Raspberry	Framboeseira	✗	✗	food
Rosales	Urticaceae	*Cecropia Pachystachya*	Ambay Pumpwood	Embaúba	✓	✓	pioneer / timber
Sapindales	Anacardiaceae	*Anacardium Occidentale*	Cashew	Cajueiro	✓	✓	food
Sapindales	Anacardiaceae	*Mangifera Indica*	Mango	Mangueira	✗	✗	food
Sapindales	Anacardiaceae	*Schinus Molle*	Peruvian Pepper	Aroeira-Salso	✗	✗	ornamental / aromatic
Sapindales	Anacardiaceae	*Schinus Terebinthifolia*	Pink Pepper	Aroeira-Vermelha	✓	✓	ornamental / aromatic
Sapindales	Anacardiaceae	*Spondias Purpurea*	Jocote	Ciriguela	✗	✗	food
Sapindales	Meliaceae	*Melia Azedarach*	Chinaberry Tree	Cinamomo	✗	✗	timber
Sapindales	Rutaceae	*Citrus Reticulata*	Tangerina	Tangerina	✗	✗	food
Sapindales	Rutaceae	*Citrus x Latifolia*	Lime	Limão Taiti	✗	✗	food
Sapindales	Rutaceae	*Citrus x Limonia*	Rangpur	Limão Caipira	✗	✗	food
Sapindales	Rutaceae	*Citrus x Limonia*	Rangpur - Orange Peel	Limão Cravo	✗	✗	food
Sapindales	Rutaceae	*Citrus x Sinensis*	Orange	Laranja	✗	✗	food
Sapindales	Sapindaceae	*Litchi Chinensis*	Lychee	Lychea	✗	✗	food

Order	Family	Scientific name	Common name	Brazilian name	Native to Brazil	Locally native	Function
Sapindales	Sapindaceae	*Sapindus Saponaria*	Soap Nut	Saboneteira	✅	✅	soap
Solanales	Convolvulaceae	*Ipomoea Batatas*	Sweet Potato	Batata Doce	❌	❌	food
Solanales	Solanaceae	*Capsicum Annuum*	Bell Pepper	Pimentão	❌	❌	food
Solanales	Solanaceae	*Capsicum Sp.*	Big Red Pepper	Pimenta Vermelho Grande	✅	❌	aromatic
Solanales	Solanaceae	*Capsicum Sp.*	Small Red Pepper	Pimenta Vermelho Pecuena	✅	❌	aromatic
Solanales	Solanaceae	*Physalis Sp.*	Physalis	Physalis	✅	❌	food
Solanales	Solanaceae	*Solanum Lycopersicum*	Tomato	Tomate	❌	❌	food
Solanales	Solanaceae	*Solanum Tuberosum*	Potato	Batata	❌	❌	food
Zingiberales	Musaceae	*Musa Sp*	Banana	Banana	❌	❌	food
Zingiberales	Zingiberaceae	*Curcuma Longa*	Curcuma	Açafrão-Da-Terra	❌	❌	aromatic
Zingiberales	Zingiberaceae	*Zingiber Officinale*	Ginger	Gengibre	❌	❌	aromatic / medicinal

Appendix III

Description of locations where soil sample have been collected. Chemical soil tests have been conducted by CIDASC.

Abbreviation	Location
Norte	*Face Norte da casa,* North face of the house
Sul	*Face Sul da casa,* South face of the house
Morro	*Alto do morro,* Top of the hill
Baixa	*Baixa Lest,* Lower eastern part
Rancho	*Atras do rancho,* Behind the rancho
Frente	*Frente do terreno,* Entrance of the terrain
Old	Older agroforestry system (approx. 10y old)
New	New agroforestry system (approx. 1y old)
Grass	On the hill vegetated by grass, north face of the house
Swamp	Taken from the swampy area, behind the rancho

Soil samples have been collected at four locations, depicted in red in the figure below, for the chemical soil analysis and at 10 locations for the pfeiffer chromatography, depicted in red and blue, plus two external locations.

In the 2024 samples the values for P and K are expressed in mg/l, while they were measured in ppm in the old tests. If 1L soil weight 1kg, then mg/l = ppm. However, 1l of soil weighs more than 1kg, typically sandy soils weigh 1.65 kg/l (Zeri et al., 2018). The bulk density of the soils here has not been measured, therefore I will use a slightly more conservative estimate of 1.5 kg/l to transform all the measurements into ppm.

[mg/l = ppm * bulk density (kg/l)]

All of the collected soils, dried and sieved. Clear colour differences are visible. The compost is very dark, deep sand yellow, and other sand samples are different tints of brown/darkish, depending on quantity of organic matter.

Collection location description

The older agroforestry system has been planted in the years 2010-2016 and has seen extensive management to increase fertility and health of the soil. All of the external inputs described have been applied continuously to improve the soil quality. The sample has been collected at the foot of a macadamia tree that has received a lot of maintenance and attention over the years.

The new agroforestry system was planted during the summer PDC, January of 2023. It has received a lot of the external inputs when the system was implemented, such as organic compost from a local initiative that composts food waste and 6 months' worth of fertilizer from the dry toilet. After implementation it has continuously been receiving organic biomass, mainly from margaridão and dried grass. The sample has been collected roughly in the middle of the system, in between mandioca (cassava) plants.

The grass sample has been collected from the field next to the new system, about halfway up the hill. This sample serves as a control, as the only type of management that this field has received is mowing of the grass. Generally, most of the grass is collected and used as organic biomass source for the agroforestry systems, so if anything, this area should have lower nutrient and organic matter values than in 2007. This sample would best be compared to the first two samples of 2007, as it is in similar terrain, more specifically, it is north of the house.

The swampy area is the lower part of the land that is connected to a small lake. It is a marshy area, where the groundwater is very high, at times the land is completely inundated. The soil seems to be less sandy, or at least less permeable, and there seems to be more organic matter accumulation. This area has not received any particular kind of management, some producing trees such as banana and bamboo have been planted, but has not received any specific external inputs. The area start behind the Rancho, so should be similar to the sample "*Atras do Rancho"*

Next to these four locations, soil has been collected from four locations on the land, one compost sample and one natural forest sample. The sample 'next to chicken' has been taken next to the chicken run under a big, approximately 10-15 year old avocado tree. The sample 'Hill next to volley' has been taken close to the entrance of the land, on top of the grassy hill next to the volleyball field. The sample 'Eucalypt hill' has been taken on the top of the hill, close to the spirulina house under some Eucalyptus trees, with some other small native pioneer plants and grasses. The sample 'deep sand' has been taken at a depth of approximately 1m, next to the spirulina house, where sand has been dug away to make the surface level. These locations have not received any specific management other than pruning or mowing of grass. The sample 'Fertilised new-new' has been taken from the newest agroforestry system, that has been constructed one week prior to sample collection as described in the section permaculture and is in close proximity to the 'Eucalypt Hill' sample.

The compost sample has been taken from a local composting initiative that collects organic waste from bars and restaurants and turns this into fertile compost. The soil from the natural forest has been taken from a location nearby, next to the freshwater lagoon, which has been dense ombriphilous forest since the first detailed maps of 1957.

Appendix IV

The pfeiffer chromatography was conducted as described in the *Guia practica,* available for download at http://www.infoteca.cnptia.embrapa.br/handle/doc/1097113. As laboratory equipment was not available, easily accessible at home tools where used, such as jars instead of Erlenmeyer flasks and their lids for petridishes.

Figure 35 Pfeiffer chromatography, conducted using at home available tools

Interpretation chromatography

To interpret the chromas it is best practice to compare them to a healthy forest soil sample and score them on the integration, channels, spikes and colour, as demonstrated in the table below. There is also computational technology nowadays, which might make it easier to uniformly assess samples.

Score	Integration	Channel	Spike	Colour
1	concentric rings, without integration	absent	absent	Homogenous, dark, boring, not intense
2	some rings, abrupt integration	some radial lines	pointed spikes	grey/brown
3	clear patterns	radial lines to narrow plumes	hollow tubed spikes	beige
4	gradual integration	chanells cover whole chroma	some open in patches	expensive whitish
5	diffuse integration, patterns interlock	Thick and prominent	spikes all open	yellow, creme, intens and heterogenous

Scores of chromatograms

Sample	Integration	Channel	Spike	Colour	AVERAGE	SCORE	Remarks
Forest (0-3cm)	5	5	3	5	5	VERY GOOD	Zone 2 much larger, compared to 3
Forest (5-10cm)	5	5	2	5	4	GOOD	opposite, 3 much larger than 2
Forest (15-20cm)	5	5	2	5	4	GOOD	as above; where are the spikes????
Compost (pre-siev)	5	5	4	5	4	GOOD	2nd Best developed chroma
Compost (pre-siev) 1g??	2	3	1	4	3	GOOD	not good developed
Compost (not pre-siev)	4	5	4	4	5	VERY GOOD	
Old system (0-3cm)	5	5	5	5	5	VERY GOOD	best
Old system (5-10cm)	5	5	5	5	5	VERY GOOD	best
New system (0-3cm)	2	2	2	2	2	BAD	
New system (5-10cm)	2	2	1	2	2	BAD	
Grass south (0-3cm)	2	2	3	2	2	BAD	
Grass south (5-10cm)	2	1	1	1	1	VERY BAD	
Rancho (0-3cm)	5	5	5	5	5	VERY GOOD	beautiful
Rancho (5-10cm)	2	2	2	2	2	BAD	disastrous, very interesting difference
Eucalypt hill (0-3cm)	4	5	3	5	4	GOOD	
Eucalypt hill (5-10cm)	4	5	3	4	4	GOOD	
Fertilized new-new system	4	3	4	4	4	GOOD	
Deep sand	1	1	1	1	1	VERY BAD	
Next to chicken avo (0-3cm)	2	2	1	2	2	BAD	
Next to chicken avo (5-10cm	1	1	1	1	1	VERY BAD	No aeration, no micro-organisms, nothing happening..
Top grass hill volley (0-3cm)	2	2	2	2	2	BAD	
Top grass hill volley (5-10cm	3	2	1	2	2	BAD	

Appendix V

‘New’ Agroforestry system constructed during summer PDC, January 2023. The system develops rapidly in the Santa Catarina climate. Picture on the left was taken when I first arrived, October 11th , and on the right just before I left, June 11th.

The newest lines of agroforest are designed as descripted in the permaculture section. A path is made using tree trunks, soil is amended with fertiliser and compost, consequently seeds and young trees are planted and covered with grass. After one month, some of the crops such as broccoli and pumpkin were growing rapidly, see the picture below. The young trees will take more time to grow and would ‘enjoy’ some shade from these helping crops.

The following images depict the houses build at Morada Ekoa. To demonstrate the possibilities using bioconstruction practices.

Casa Mãe:

Casa Spirulina, and the river system.

Casa Spirulina

Chalet Butia

Chalet Jussara

Appendix VI

ABUNDANCE