

Overview of eucalypt plantation in Brazil

Amanda Castanho Albuquerque

Guilherme Oguri

Beatriz Zerbinato Balista

Muedanyi Ramantswana

Saulo Philipe Sebastião Guerra



FICHA CATALOGRÁFICA ELABORADA PELA SEÇÃO TÉCNICA DE AQUISIÇÃO E TRATAMENTO DA INFORMAÇÃO - DIRETORIA TÉCNICA DE BIBLIOTECA E DOCUMENTAÇÃO - UNESP - FCA - LAGEADO - BOTUCATU (SP)

096 Overview of eucalypt plantation in Brazil
/ Amanda Castanho Albuquerque ... [et al.]. - Botucatu : FEPAF, 2024
34 p. : fots. color., grafs., ils. color., tabs

Available at: <https://www.forsilvitech.com/>
ISBN 978-65-89571-14-8 (eBook)
Includes bibliography

1. Forest plantation. 2. Forest production. 3. Forest management. 4. Silviculture. I. Albuquerque, Amanda Castanho. II. Oguri, Guilherme. III. Balista, Beatriz Zerbino. IV. Ramantswana, Muedanyi. V. Guerra, Saulo Philippe Sebastião. VI. Fundação de Estudos e Pesquisas Agrícolas e Florestais. VII. Título.

CDD 23.ed. (634.973766)

Authors



AMANDA CASTANHO ALBUQUERQUE

Forest Engineer from The Federal University of São Carlos (UFSCar) in Sorocaba. Currently, member of the John Deere mechanized planter project through the Foundation for Research and Agricultural and Forestry Studies (FEPAF). Additionally, doing a Master of Business Administration in Project Management at USP/Esalq.



GUILHERME OGURI

Forest Engineer, Master, and Doctor of Agronomy from São Paulo State University (Unesp), School of Agricultural Sciences, Botucatu. Currently Executive Coordinator of the Cooperative Program on Forest Mechanization and member of the technical staff for the Forest Manager Preparation Program (PPGF) at the Forestry Research Institute (IPEF).



BEATRIZ ZERBINATO BALISTA

Forest Engineer from São Paulo State University (Unesp), School of Agricultural Sciences, Botucatu. Executive Assistant of the Cooperative Program on Forest Mechanization and Automation at the Forestry Research Institute (IPEF). PhD student in the Bioenergy Program at the Bioenergy Research Institute (IPBEN/Unesp).



MUEDANYI RAMANTSWANA

Forest Engineer, Masters (Nelson Mandela University), and Doctor of Forest Science at University of Pretoria. Senior Lecturer and programme coordinator at the Nelson Mandela University in the Department of Forestry, Natural Resource Science and Management Cluster (Faculty of Science) based in George, South Africa.



SAULO PHILIFE SEBASTIÃO GUERRA

Forest Engineer, Master, and Doctor of Agronomy from São Paulo State University (Unesp), School of Agricultural Sciences, Botucatu. Professor in the Department of Rural Engineering and Socioeconomics at the School of Agricultural Sciences/Unesp, coordinator of the Agroforestry Biomass and Bioenergy Laboratory (LABB/IPBEN), and scientific head of the Cooperative Program on Forest Mechanization and Automation at the Forestry Research Institute (PCMAF/IPEF). Associated Researcher at Nelson Mandela University. Currently Director of the Unesp Innovation Agency (AUIN/Unesp).

Summary

1. Eucalypt plantations	5
Planted area in Brazil	5
Forest cycle	6
Operations	7
Quality analysis	8
Attributes of interest	9
Main planted species	10
Frost tolerant species	11
Genetic improvement of Eucalyptus	12
2. A good eucalypt seedling	14
3. Substrates	15
Substrate materials	15
4. Seedling nursery	16
Seedling process	17
Nursery installation	18
Irrigation	18
Plant selection in nurseries	19
Renasem (National Registry of Seeds and Seedlings)	20
5. Main eucalypt pests	21
6. Main eucalypt diseases	22
7. Climate	23
Brazilian rainfall index	23
Climate classification	24
Precipitation	25
8. Soils	25
Types of soil	26
Soil with eucalypt plantation	26
Soil properties	27
SiBCS (Brazilian Soil Classification System)	28
Description of soils	29
Soil degradation	31
9. Landform classification	32
Description of landforms	35
10. Slope condition	36
References	37

1 Eucalypt plantations



Brazil has around 10 million hectares of timber plantation and 6 million hectares of conserved area by the Brazilian timber industry.

Eucalypt covers 76% of the planted area, remaining the most cultivated species, totaling 7.6 million hectares.

Pine makes up 19% of the planted area, 1.9 million hectares.

Other species, such as rubber trees, teak, and wattle, correspond to 5% of the planted area, 0.36 million hectares.

Planted area in Brazil

Eucalypt plantations, mainly located in the Southeast and Midwest region, are responsible for 1.2% of Brazilian GDP, generating 2.6 million direct and indirect jobs. Brazilian roundwood production reached a record of 158.284 million m³ in 2022.

29%

Minas Gerais

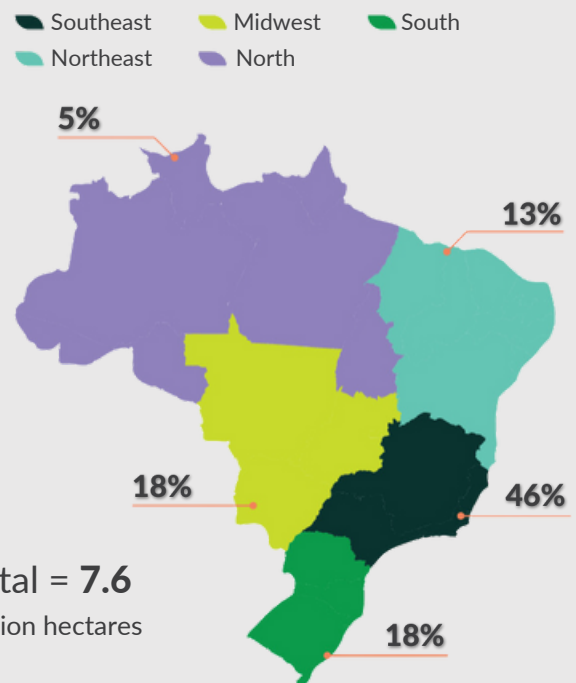
15%

Mato Grosso do Sul

13%

Sao Paulo

Share of planted area per region: eucalypt, 2022 (%)



(IBÁ, 2023)

1 Eucalypt plantations

Forestry cycle



Forestry operations are carried out each year in a eucalypt planted forest.



0 - 1 year

Establishment

- Soil preparation
- Ant control
- Pre-emergent application
- Post-emergent application
- Base fertilization
- Planting
- Irrigation
- Monitoring and assesment



2 - 4 years

Stand tending

- Surface fertilization
- Ant control
- Monitoring and assesment
- Weeding
- Pest and diseases control
- Forest inventory



5 - 7 years

Pre-harvest

- Weeding
- Ant control
- Liming (next cycle)
- Monitoring and assesment

1 Eucalypt plantations

Operations

MAIN ACTIVITIES	MAIN OBJECTIVE	RANGE	USUAL PRODUCTS	SOME EQUIPMENTS
Soil preparation	Provide adequate conditions for the development of the seedling's roots.	Depth: 0.3 – 1.0 m	-	Ripper, subsoiler, excavator subsoiler
Ant control	Prevent ant attacks/infestation.	Dose: 4 to 10 g/m ² of disturbed soil by ants	Sulfloramid, Fipronil	Ant bite back pack distributor, tractor mounted spreader, drone
Herbicide pre-emergent application	Prevent the emergence of weeds before planting the seedlings.	Dose: defined by the product and weed condition	Oxiflourfen, Flumioxazin, Sulfentrazone, Imazapyr	Boom sprayer, backpack pump sprayer, drone
Herbicide post-emergent application	Eliminate weeds until the initial development of the seedlings.	Dose: defined by the product and weed condition	Glyphosate, Carfentrazone, Oxiflourfen	Windbox sprayer, boom sprayer, backpack pump sprayer, drone
Base fertilization	Provide nutrients necessary for the initial development of seedlings.	Dose: 300 – 400 kg/ha	NPK	Fertilizer spreader, side fertilizer
Planting	Position the seedlings correctly within the planting line.	Stand tending: 1,000 – 1,666 seedlings/ha	Eucalypt clone seedlings	Planting heads, planting tubes
Post planting irrigation	Provide the necessary water conditions for the initial growth of seedlings.	Dose: 2.0 – 5.0 liters/seedling	Water and hydrogel	Automated irrigator, manual irrigator (hose and pump)
Monitoring and assessment	Provide necessary information for better management.	Frequency: up to 3 times/cycle	-	Forestry caliper, clinometer, drones, LiDAR, satellite images
Surface fertilization	Complement the supply of nutrients for better initial development.	Dose: 150 – 200 kg/ha	NPK + Micronutrients	Fertilizer spreader
Liming	Control the soil acidity by neutralising the effects of acids.	Dose: 1,0 – 2,5 t/ha	Calcium	Fertilizer spreader
Forest inventory	Measure the wood volume in the forest.	Frequency: annual or biannual since the second year after planting	-	Calipers, clinometers, height measuring tools and compasses, LiDAR

P.S: The indication of the range, main products and equipment does not indicate a recommendation for use by the authors.

1 Eucalypt plantations

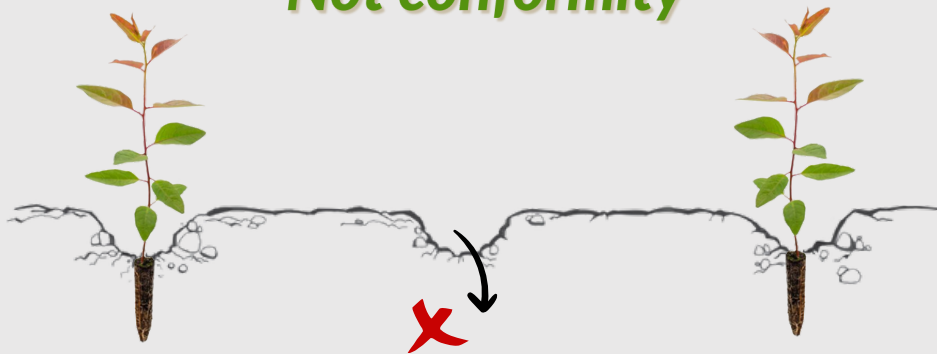
Quality analysis

Conformity

The root plug must be entirely in contact with the soil, with a burial of a maximum of 2 cm of the root collar being tolerated.



Not conformity



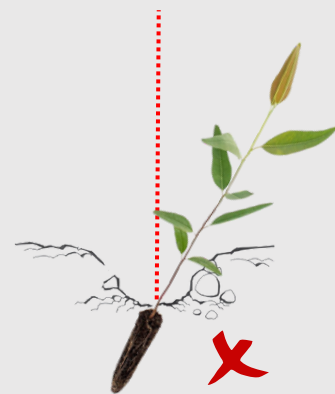
Empty planting position



Deep planting



High planting



Tilted planting

1 Eucalypt plantations

Attributes of interest

The eucalypt has several attributes of interest in the context of planted forests.

- Fast growth: reaches cutting age 5 to 7 years after planting.
- High productivity, estimated at 32.7 m³/ha/year (MAI with bark).
- Low nutritional requirements: performs well even in low-fertility soils.
- Low competition between plants: good growth even with reduced spacing.
- Low incidence of pests and diseases: severe damage occurs mainly from attacks by leaf-cutting ants and termites.
- Stem form: tends to have straight and trunks that are large in height, suitable for various purposes.
- High basic wood density.
- High quality wood for use as firewood, charcoal, and cellulose derivatives.
- High coppicing capacity.
- Easy to produce seedlings, due to the use of cuttings, and a short period for seedling formation (between 60 and 90 days).



(Oguri, 2024)

1 Eucalypt plantations

Main planted species

Eucalyptus grandis

Tall and good growth

One of the most notable species within the *Eucalyptus* genus. It stands out for its rapid growth and high wood productivity, making it a popular choice in paper and pulp production. The wood is highly valued for its quality and is often utilized in manufacturing papers and other cellulose-derived products.

The climate in the natural occurrence region of this species is generally warm and humid. The development of the species' crop is significantly limited by the occurrence of frosts.



Eucalyptus urophylla

A new energy solution

Similar to *E. grandis*, *E. urophylla* is also a fast-growing species with high wood productivity. Its versatility makes it a preferred choice in paper and pulp production. Additionally, this species is valued for its ability to produce energy. The biomass from *Eucalyptus urophylla* is a promising source of renewable energy, contributing to the search for more sustainable energy sources.

1 Eucalypt plantations

Frost tolerant species

Eucalyptus benthamii

E. benthamii thrives in areas with an average annual temperature of up to 14.5°C and exhibits notable frost tolerance, making it a popular choice for planting in subtropical regions. The species prefers soils on flat terrain or slopes with gentle inclines, preferably with clayey texture and a minimum annual precipitation of 800 mm in colder regions.



Eucalyptus dunnii

Stands out for its rapid growth, uniformity of stands, and resistance to moderate frosts, making it recommended for the Southern region, particularly at altitudes between 500 m and 1,000 m. In these areas where harsh winters challenge many other eucalypt species, *E. dunnii* proves to be adapted and resilient.

1 Eucalypt plantations

Genetic improvement of *Eucalyptus*

A technology implemented in the forestry sector is genetic improvement programs with *Eucalyptus*, involving the selection of clones that enable the use of material with desirable characteristics and increased production.



Eucalyptus cloning is carried out to increase the productivity of planted forests, allowing for the uniformity of raw material and improving wood quality. This results in greater resistance to adverse factors such as drought, water deficit, pests, and diseases.

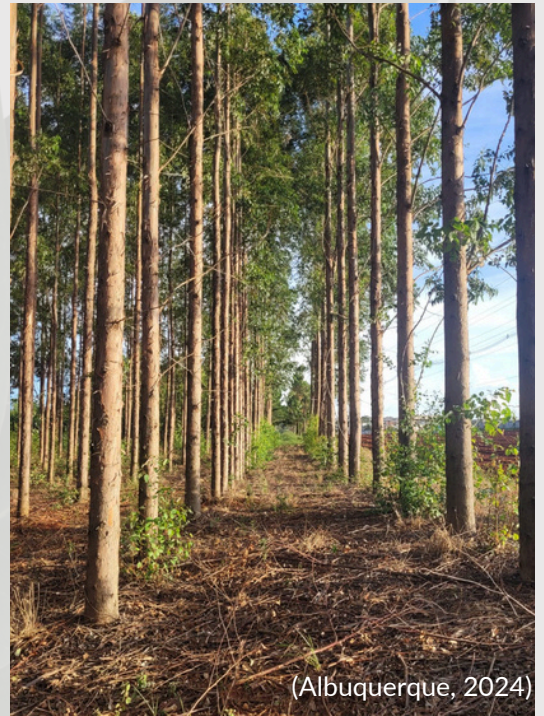
Additionally, cloning aims to enhance adaptability to the environment and improve wood's physical and chemical properties. In summary, breeding programs aim to achieve high production rates, especially in volume, through good height growth and its correlation with diameter. Currently, cloning is achieved through species hybridization, combining individuals with distinct characteristics.

1 Eucalypt plantations

Genetic improvement of *Eucalyptus*

E. grandis x *E. urophylla*

One of Brazil's most widely used hybrids in reforestation projects, known for its remarkable productivity. It is recommended for tropical areas as it can be sensitive to mild frosts. Precipitation is one of the main factors influencing its productivity.



There are recommendations to minimize the impact of cold events, such as planting before the frost period and avoiding low-lying areas and south-facing slopes exposure. Additionally, planting in bare soils can reduce the damage caused by cold events, especially during the initial establishment of seedlings. These measures help protect *E. grandis* x *E. urophylla* and optimize its productivity.

2 A good eucalypt seedling

Leaf-sets

- Three pairs of leaves or more
- Absence of symptoms of nutritional deficiency
- Good leaf water potential indicating seedling hydration level

Stem form

- Stem diameter 2.5 - 4.5 mm
- Indicate the survival and growth capacity of seedlings in the field

Root plug

- Uniform composition
- Low density to facilitate handling and development
- Ability to absorb and retain water, even when dry
- Good porosity to allow adequate drainage of excess water during irrigation and rainfall, maintaining good aeration
- Absence of toxic substances, pathogens, invasive plants, insects, and excess salts



(Oguri, 2022)

3 Substrates



(Oguri, 2024)

Additionally, substrates should be:

- Easy to find in sufficient quantity;
- Easy to handle in the nursery;
- Have uniform consistency between batches;
- Form clumps that do not easily break apart during planting.

Substrates for seedlings can be made from a single material or a combination of several, such as soil, organic compost, vermiculite, sand, carbonized rice husk, worm castings, crushed coconut fiber, and others. They help support the seedlings while roots develop, ensuring proper aeration, moisture, and nutrients for growth.

Substrate materials

Vermiculite + Carbonized rice husk + Crushed coconut fiber



(Oguri, 2024)

4 Seedling nursery



(Albuquerque, 2024)

Seedling production is crucial for the success of a forestry plantation. If the seedlings are not of quality, productivity may be affected, resulting in future losses. Planning the nursery creation well and choosing production techniques that meet the company's needs is essential.

Experienced individuals should manage the seedling production process due to the unforeseen circumstances that may arise.

To obtain seedlings, the producer must consider the following scenarios:

- 1. Procuring seedlings from third parties:** It is important to verify the origin of the material and assess the quality of the seedlings to be acquired (size, appearance of aboveground parts, and root system).
- 2. Producing seedlings for self-use:** The nursery sizing will be determined based on the number of seedlings produced. In this case, the wood needs (quantity and final use) to meet the farm's requirements, as well as the possibilities of timber sales.
- 3. Establishing a commercial nursery:** This requires studies on the economic viability of the venture, considering market potential, the level of nursery sophistication, and the diversity of species to be utilized.

4 Seedling nursery

Seedling process



The process of seedling production can be carried out manually, semi-automatic, or automatic equipment, depending on the annual production requirements and the cost-benefit analysis of investing in larger equipment.

The seedlings should be ready for field planting after three to four months at the nursery.



4 Seedling nursery

Nursery installation

The nursery should be strategically located for easy access, have reliable water availability, and be shielded from winds, ants, or animal interference.

A basic infrastructure for a nursery producing eucalyptus seedlings on a commercial scale should include areas for production and selection of parent plants. These areas should be divided into a greenhouse, used during the initial development phase of the seedlings, and a hardening area, used for acclimating the seedlings before dispatch. Additionally, it should have a laboratory, a supply shed, and tool storage.



Irrigation



Water is crucial in the nursery, and the required quantity varies depending on the region, climate, type of substrate, plant species, and growth stage of the seedlings. More frequent irrigation may be necessary in drier regions or during periods of intense heat. If the seedlings are in tubes, they require more water because these containers are small and retain less water. Substrates used in tubes also retain less water.

4 Seedling nursery

Plant selection in nurseries

In the selection of eucalyptus seedlings, they are classified as small, medium, and large according to size. The first selection occurs when the seedlings reach about 10 cm in height and the second when they reach an average of 20 cm in height.

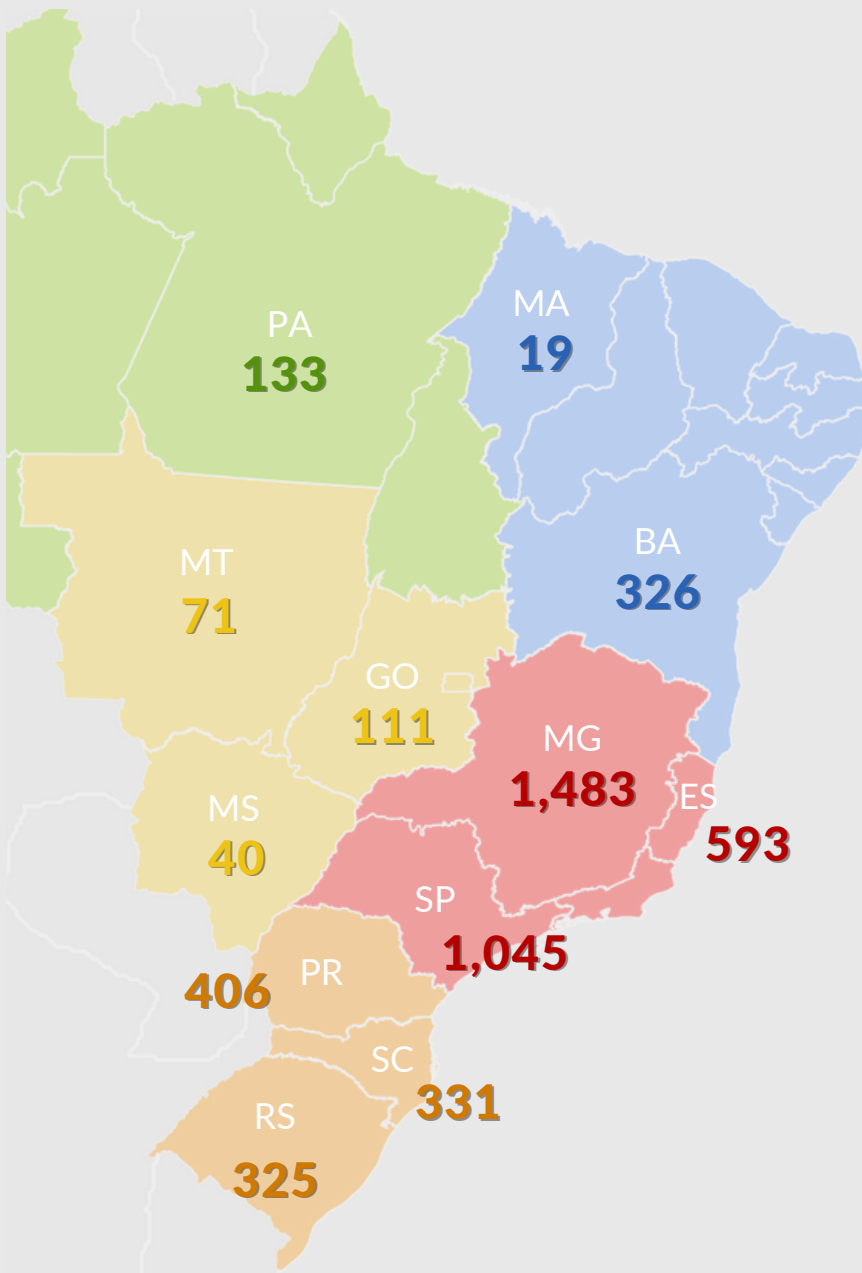
After selection, smaller seedlings may receive additional fertilization. The third selection occurs at dispatch, considering height growth, stem diameter, stem form (not forked and not crooked), or any signs of diseases.



4 Seedling nursery

Renasem

(National Registry of Seeds and Seedlings)



(Renasem, 2024)

Renasem is a valid authorization throughout Brazil, linked to the Ministry of Agriculture, Livestock and Food Supply (MAPA), allowing activities under current legislation. Upon registration, individuals and legal entities are authorized to operate as traders and producers of seedlings.

The purpose of obtaining Renasem is to ensure the identification and quality of the material produced, marketed, and used throughout the national territory. Based on the data from the Renasem portal, a map has been created showing the number of nurseries registered in the leading eucalyptus-producing states.

5 Main eucalypt pests

Forest pest control is carried out annually, especially in the fight against leaf-cutting ants. These pests cause great damage, especially in the first two years of the forest's life, and limit production in forestry enterprises. They can be observed in the nurseries and fields.

Nursery

Longtailed mealybug



Pseudococcus longispinus

White fly



Dialeurodicus tessellatus

Gall wasps



Leptocybe invasa

Field

Red gum lerp psyllid



Glycaspis brimblecombei

Bronze bug



Thaumastocoris peregrinus

Snout beetle



Gonipterus platensis

Acromyrmex spp.



When starting eucalypt plantations, leaf-cutting ants are a serious problem. These insects can defoliate mature trees in a single night and cause significant damage to newly planted seedlings.

Belonging to the genera *Atta* and *Acromyrmex*, they use fresh plant substrates to cultivate the fungus they consume.

Atta spp.



Main eucalypt diseases

With the expansion of forest plantation areas, the inadequate use of silvicultural techniques, management, and inappropriate genetic material, caused an increase in the number of diseases in eucalyptus farming. Under favorable conditions for pathogens, there is a significant loss in productivity, with diseases occurring both in nurseries and in the field.

Nursery

Eucalyptus rust



(Mafia, 2023)

Austropuccinia psidii

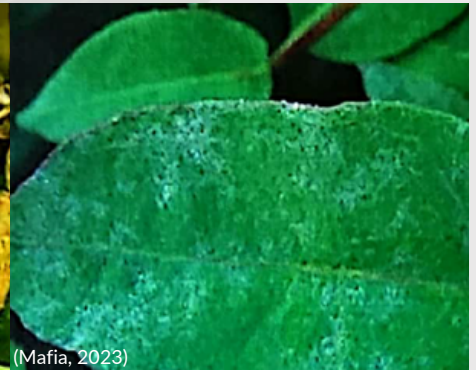
Gray mold



(Mafia, 2023)

Botrytis cinerea

Oidium



(Mafia, 2023)

*Podosphaera
pannosa*

Field

Eucalyptus rust



(Mafia, 2023)

Austropuccinia psidii

Ceratocystis wilt



(Mafia, 2023)

Ceratocystis fimbriata

Bacterial wilt



(Mafia, 2023)

Ralstonia solanacearum and *R.
pseudosolanacearum*

7 Climate

Knowing the climate data allows for optimizing productivity and making appropriate eucalypt choices.

Frost is one of the main limitations to the eucalypt development. All eucalypt species are sensitive to very low temperatures, which challenge cultivation in temperate climate regions. Although some species grow quickly and withstand frosts at commercially acceptable levels, most suffer damage, especially during unusual frosts.



Most species are harmed below 0°C, with only a few surviving temperatures between -15°C and -18°C.

Water stress is the primary limiting factor for eucalyptus productivity in tropical climates. In these regions, the *Eucalyptus* "urograndis", resulting from the crossbreeding of *E. grandis* and *E. urophylla*, is commonly cultivated.

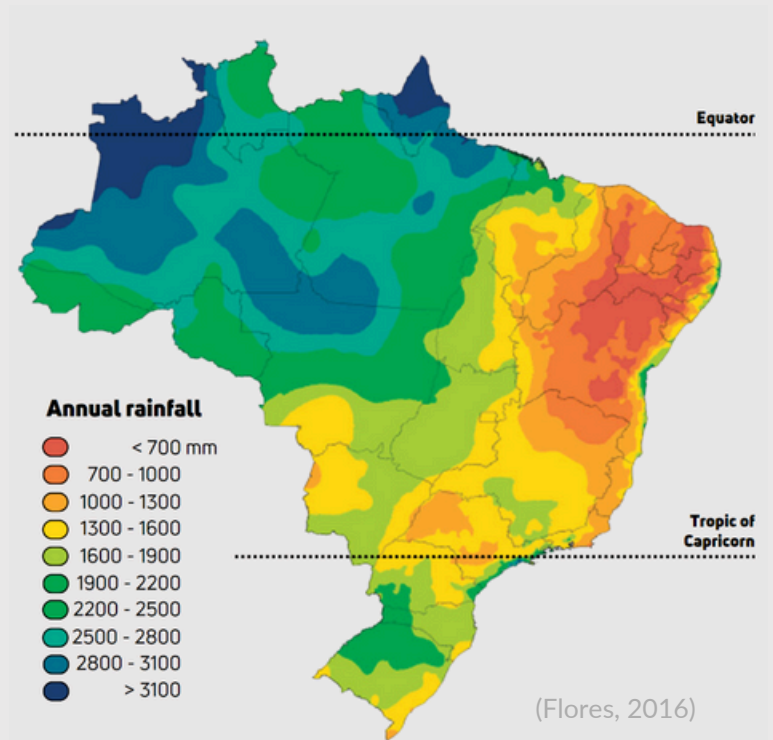
Alongside seed-produced varieties like *E. urophylla* and *E. cloeziana*, eucalypt clones such as AEC 0144, are more tolerant to water stress, and can also be grown.



7 Climate

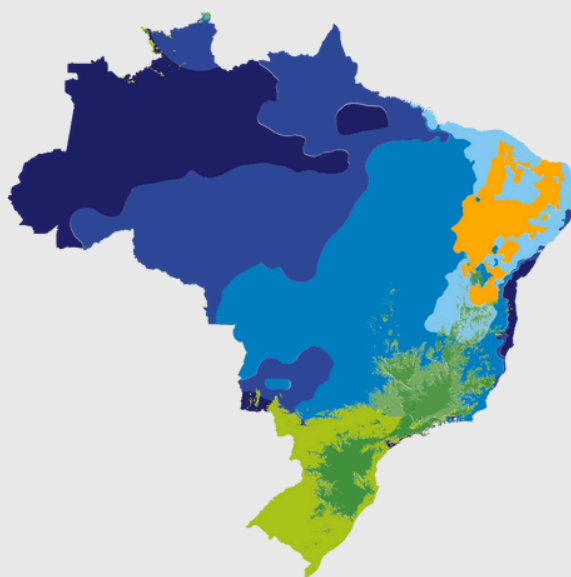
Brazilian rainfall index

Brazil is a country of continental dimensions in which the climate and rainfall vary significantly from one region to another.



Climate classification

The Köppen-Geiger climate classification is based on the vegetation, precipitation, and temperature of geographical areas, and it's of paramount importance to understand the factors and climatic elements that characterize each region of different climates, such as radiation, atmospheric pressure, humidity, latitude, altitude, continentality, among others.



A - Tropical zone

- Af - without dry season
- Am - monsoon
- Aw - with dry winter
- As - with dry summer

B - Dry zone

- Bs - semi-arid**
- BSh - low latitude and altitude

C - Humid subtropical zone

Cf - oceanic climate, without dry season

- Cfa - with hot summer
- Cfb - with temperate summer

Cw - with dry winter

- Cwa - and hot summer
- Cwb - and temperate summer
- Cwc - and short and cool summer

Cs - with dry summer

- Csa - and hot
- Csb - and temperate

(Alvares et al., 2013)

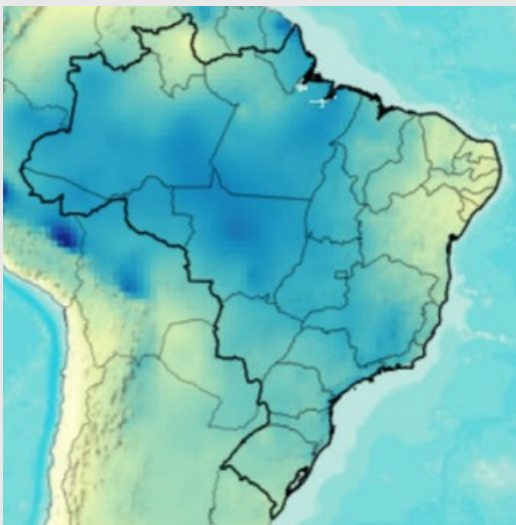
7 Climate

Precipitation

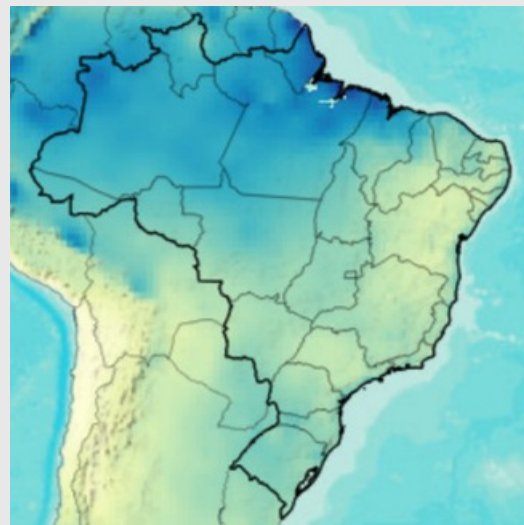
The surface air temperature varies according to the regions and seasons of Brazil, owing to its diversity and vast territorial extent.

Observed Climatology of Brazil's Precipitation

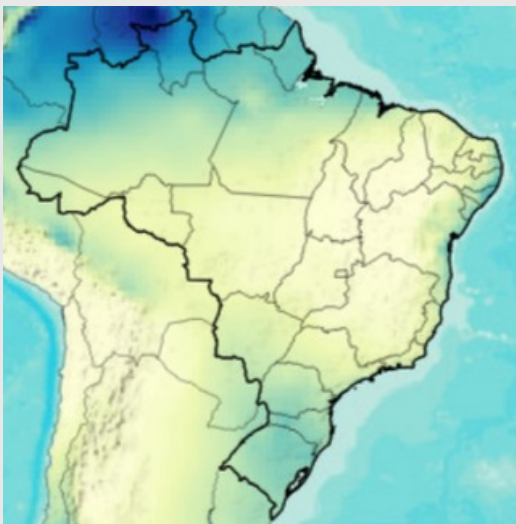
DEC - JAN - FEB



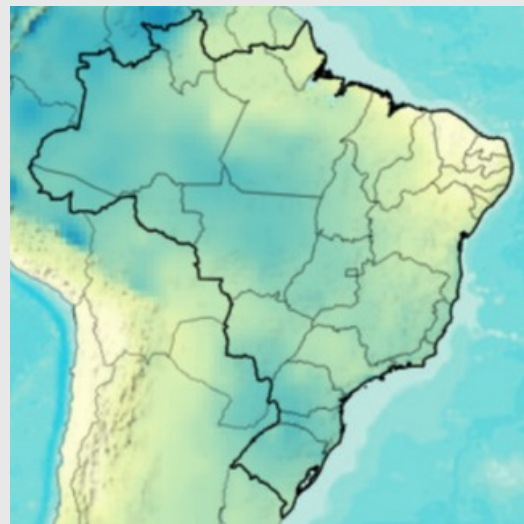
MAR - APR - MAY



JUN - JUL - AUG



SET - OCT - NOV



Precipitation (mm)



(Climate Change Knowledge Portal, 2024)

8 Soils

Finding soils that fit into just one of these groups is rare. Most soils are mixed and classified according to the material most commonly found in their composition. The main criterion for this classification is evaluating the size of the grains that make up the soil. To evaluate soil, we can divide it into three major groups: **Sandy**, **Clay**, and **Silty**.

Types of soil

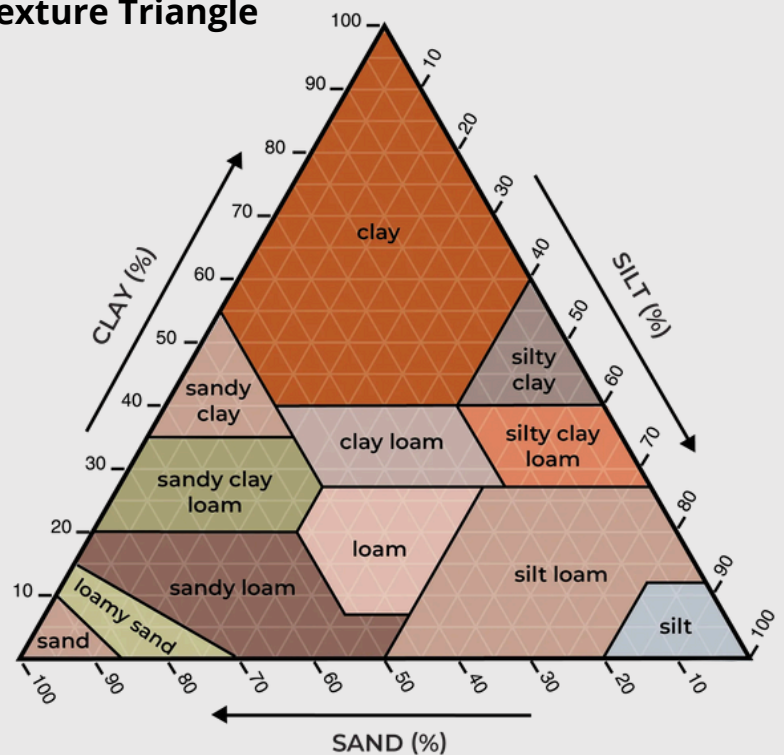
Sandy soil: These soils have a higher proportion of sand, ranging from coarse to medium to fine grains visible to the naked eye. The problem with sand is that it lacks cohesion, where its grains separate from each other when dry. Sandy soils have high permeability, allowing water to flow through them easily.

Clay soil: Clay terrain consists of microscopic grains, vivid colors, and high impermeability. Unlike sand, clay soil has a high capacity for aggregation.

Silt soil: Falls between sand and clay, with very small grains (similar to clay) but lacking cohesion like clay. It is also considered soil with low long-term stability, prone to easy erosion and natural disaggregation.

The USDA Soil Texture Triangle

The USDA Soil Texture Triangle categorizes soil based on its sand, silt, and clay content, aiding farmers and scientists in understanding soil properties and making informed decisions for agriculture and land management. By analyzing particle proportions, it determines soil texture class, and guiding practices such as irrigation, crop selection, nutrient management, and erosion prevention. This tool is crucial for sustainable land use.



(Aqua-Yield, 2023)

8 Soils

Soil with eucalypt plantation



(Oguri, 2024)

Like any other forest, a eucalypt forest plays a crucial role in regulating the water cycle within its micro-watershed. It helps control erosion and rainfall runoff by retaining water in the canopy and trunks, allowing some to flow across the soil surface gently, and absorbing the rest through the roots or into the groundwater. A eucalypt stand is much more effective in regulating the water cycle and preventing floods.

Soil properties

Table 1. Influence of sand, silt and clay fractions on some soil properties and behavior

Soil properties	Sand	Silt	Clay
<i>Capacity to retain water</i>	Low	Medium to high	High
<i>Aeration</i>	Good	Average	Poor
<i>Drainage rate</i>	High	Slow to medium	Very slow
<i>Organic matter content in the soil</i>	Low	Medium to high	High to medium
<i>Organic matter decomposition</i>	Fast	Medium	Slow
<i>Susceptibility to compaction</i>	Low	Medium	High
<i>Susceptibility to wind erosion</i>	Moderate	High	Low
<i>Susceptibility to water erosion</i>	Low	High	Low
<i>Cultivation capacity after rain</i>	Good	Average	Low
<i>Storage capacity of nutrients</i>	Low	Medium to high	High

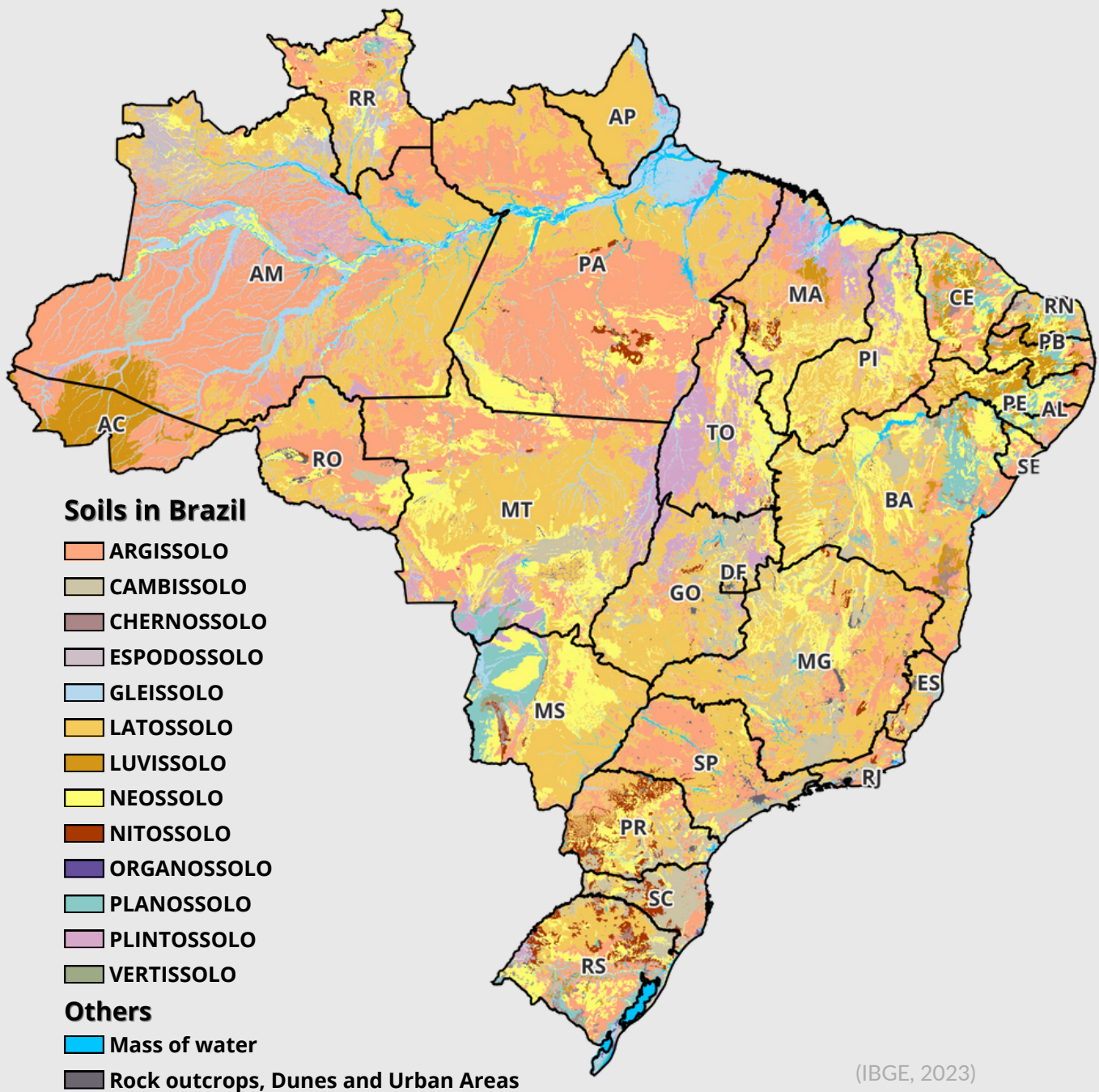
(Cooper, 2016)

8 Soils

SiBCS

(Brazilian Soil Classification System)

In Brazil, SiBCS is the official soil classification system, developed collaboratively by educational and research institutions. It's hierarchical, multicategorical, and adaptable, aiming to classify all soil types in the country, with provisions for future updates.



8 Soils

Description of soils

Table 2. SiBCS and WRB/FAO correlation with percentage in Brazil

SiBCS	WRB/FAO	Description	% in Brazil
<i>Argissolo</i>	<i>Acrisol, Lixisol, Alisol</i>	Low activity of clay, acids, accumulation of clay in subsurface	24%
<i>Cambissolo</i>	<i>Cambisol</i>	Variable clay contents, moderately developed, naturally fertile	2,5%
<i>Chernossolo</i>	<i>Chernozem</i>	Acidic mineral soils, high clay activity	0,5%
<i>Espodossolo</i>	<i>Podzol</i>	Varied drainage, sandy texture, low fertility and nutrient reserves	2%
<i>Gleissolo</i>	<i>Gleysol</i>	Poor drainage, sandy texture	4%
<i>Latossolo</i>	<i>Ferralsol</i>	Acidic mining soils with low clay fraction, well drained and evolved, equatorial and tropical regions	39%
<i>Luvisolo</i>	<i>Luvisol</i>	Non-hydromorphic, high clay fraction	3%
<i>Neossolo</i>	<i>Leptosol, Arenosol, Fluvisol</i>	Mineral or organic materials, little evolved	15%
<i>Nitossolo</i>	<i>Nitisol</i>	Very clay texture	1,5%
<i>Organossolo</i>	<i>Histosol</i>	Poorly developed soil and drainage, accumulation of plant residues	*
<i>Planossolo</i>	<i>Planosol</i>	Poor drainage, clay concentration, slow permeability	2%
<i>Plintossolo</i>	<i>Plinthosol</i>	Poor drainage, low clay fraction, excess moisture, strongly acidic	6%
<i>Vertissolo</i>	<i>Vertisol</i>	Poor drainage, high clay fraction	2%

*Unrepresentative

(SiBCS, 2018; Embrapa, 2024)

8 Soils

Soil Degradation

The impact on the physical attributes of soil under forests is linked to vehicle traffic during operations, which alters the structure and physical attributes of the soil, hindering root growth and distribution and consequently affecting forest development. During timber extraction from forested areas, machines often traverse the same route repeatedly, resulting in soil compaction and facilitating the erosion process due to increased surface runoff, leading to soil and nutrient loss.

Erosion



Water erosion contributes to soil degradation and necessitates additional nutrient investments to achieve desired productivity. Various factors such as compaction, deforestation, wildfires, urbanization, road drainage, and cultivation practices are responsible for this process.



8 Soils

Soil Degradation

Compaction

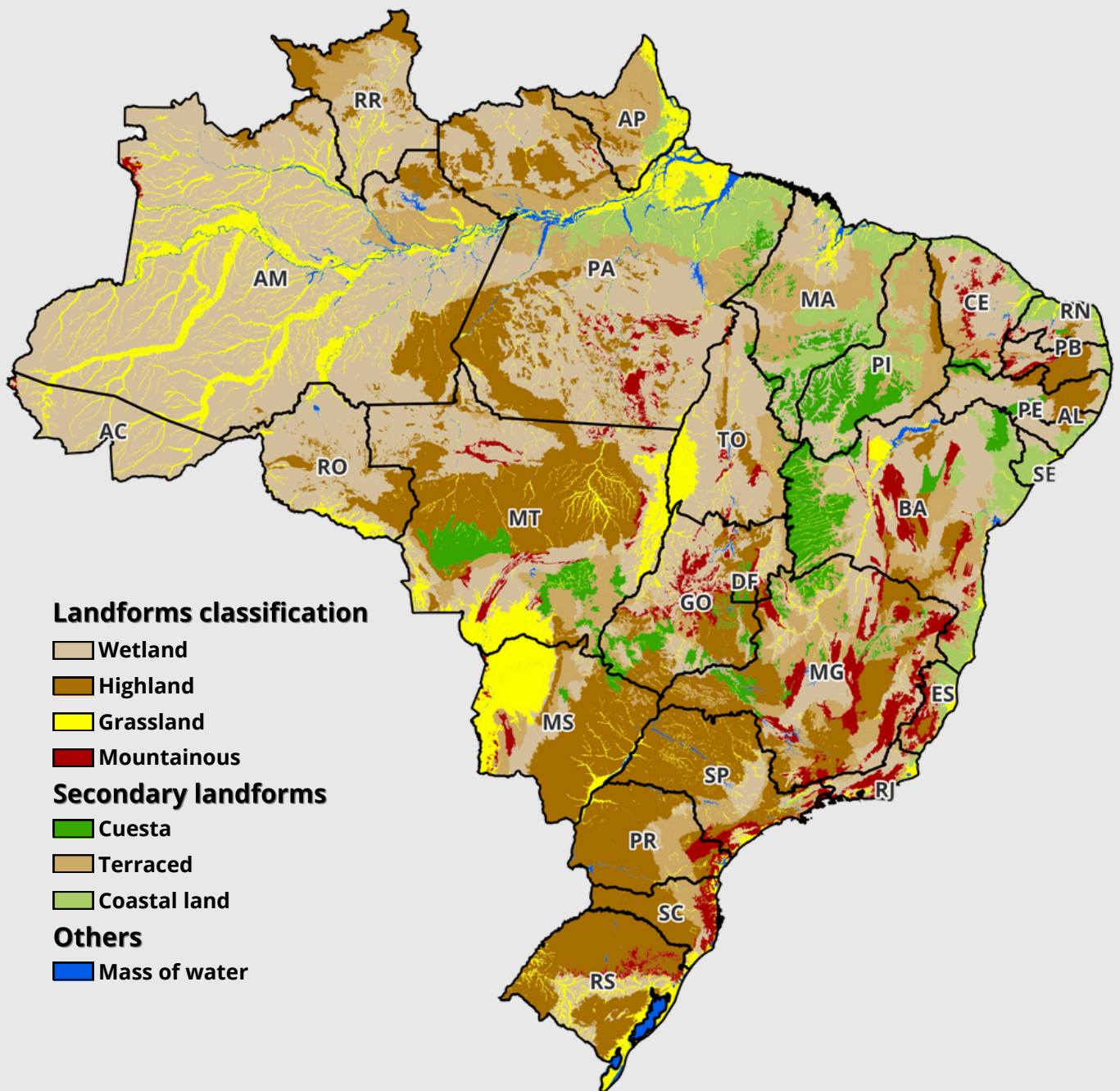


Soil compaction reduces plant growth due to its effect on root development, decreasing aeration, water, and nutrient absorption. Additionally, compaction can prevent water and nutrient movement in the soil, temporarily reducing their availability to plants or permanently compromising productivity. The effects of compaction on plant development become apparent when roots encounter mechanical resistance during growth.



9 Landform Classification

Brazil features a landform from moderate to low altitudes, with significant influence from external agents such as climate and vegetation. The landforms have been formed over geological structures primarily composed of sedimentary basins (64% of the territory) and crystalline shields (36%). Predominant landforms include wetland, highland, grassland, and mountainous. Additionally, there are secondary classifications: cuesta, terraced, and coastal land.



(IBGE, 2023)

9 Landform Classification

Description of landforms

The BDiAWeb portal is a platform to consult BDiA data to interactively share the IBGE's environmental information. With the platform, it was possible to collect the percentages of terrain types in each state of Brazil.

Table 2. Environmental Information Database (BDiA) and the percentage in Brazil

Relief Classification	Description	% in Brazil
Wetlands	Flat or gently undulating terrain, lower than neighboring regions, rocks of various classes	40.5
Highlands	Flat or dissected terrain, high altitudes, bounded by lower surfaces, erosion processes	22
Grassland	Flat or gently undulating terrain, low altitude, sedimentary rocks	9.5
Mountainous	Jagged relief, forming ridges and summits, rocks of various classes	4
Cuesta	Flat-topped elevations, high altitudes, sedimentary rocks	4.5
Terraced	Flat or gently undulating terrain, rocks of various classes, intermediate surfaces or steps between higher and lower relief areas	13.1
Coastal land	Flat-topped elevations, low altitudes, sedimentary rocks	4.6

(BDiA, 2024; IBGE, 2023)

9 Landform Classification

Wetlands



(WWF, 2018)

Geographical regions lower in elevation than the surrounding areas. It is common for lakes to form in depressions.

Areas of varied and limited altitudes, bordered on one side by a lowered surface. They are formed by erosion caused by water or wind. The hilltops of plateaus are slightly leveled.

Highlands



(Britannica, 2024)

Grassland



(Overbeck, 2022)

Have a relatively flat surface (little or no variation in altitude). They are found in low-lying regions, formed by sedimentary rocks.

9 Landform Classification

Mountainous



(Reservas da Biosfera, 2024)

A set of mountains that are formed by the collision of tectonic plates in the Earth's crust. The soil in the regions rises to the surface, forming the mountains, which are higher than those in neighboring regions.

Cuesta



(Stefanuto, 2022)

Coastal lands



(Overbeck, 2022)

Terraced



(Overbeck, 2022)

These landforms differ in scale and specific terrain characteristics. While **“cuesta”** tend to be larger and more rugged, **“coastal lands”** are generally more extensive with smoother terrain, and **“terraced”** may be smaller and less extensive but still have flat hilltops. The English translations may vary depending on the specific context in which the terms are used.

10 Slope condition

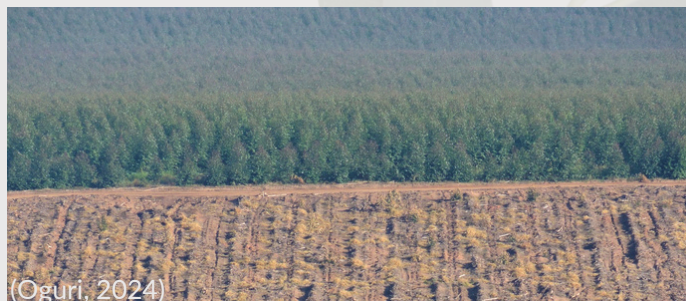
Flat (< 3%) and Gently Undulating (>3 - 8%)

Flat refers to a horizontal surface with small elevations that allow for land use throughout the year, as well as the use of common agricultural machinery and implements, without rockiness. Gently Undulating allows for land use for most of the year, with rocks/stones and elevations up to 100 meters in altitude.



Undulating (>8 - 20%) and Strongly Undulating (>20 - 45%)

Undulating features a topography with moderate slopes, with some limitations for using machinery and agricultural implements. Strongly Undulating is characterized by altitudes up to 200 m and steep slopes.



Hilly (>45 - 75%) and Steep slope (> 75%)

Hilly describes a rugged topography with rugged forms, making it unsuitable for mechanization throughout the year, with significant elevations and steep slopes. Steep terrain shares the same characteristics.



Bibliography

ALVARES, C. A.; ALMEIDA, B. O.; VAZ, R. C. **Modeling of frost-prone areas for *Eucalyptus* in Sao Paulo**. Circular Técnica IPEF, 2022, n. 219, p. 1-11.

ALVARES, C. A.; STAPE, J. L.; SENTELHAS, P. C.; GONÇALVES, J. L. M.; SPAROVEK, G. Köppen's climate classification map for Brazil. **Meteorologische Zeitschrift**, Stuttgart, v. 22, n. 6, p. 711-728, 2013.

AQUA-YIELD, **The Soil Texture Triangle**, National Agronomy Manual, USDA, 2023. Available at: <https://www.aquayield.com/the-soil-texture-triangle>. Accessed 25 April, 2024.

BAILLIE, I. C. Soil Survey Staff 1999, Soil Taxonomy. **Soil Use and Management**, West Sussex, v. 17, n. 1, p. 57-60, 2001.

BRITANNICA, The Editors of Encyclopaedia. **"Brazilian Highlands"**. Encyclopedia Britannica, 2018. Available at: <https://www.britannica.com/place/Brazilian-Highlands>. Accessed 24 April, 2024.

COOPER, M. Arquitetura e propriedades físicas do solo. In: COOPER, M.; SILVA, A. P. **Física do solo**. Piracicaba: ESALQ/USP, 2016. 49 p.

EUFRADE-JUNIOR, H. J.; SOUSA, J. M. R.; GUERRA, S. P. S. Effect of mineral fertilization and planting density in the dendrometric characteristics of fast-growing eucalypt plantations. **Ciência Florestal**, Santa Maria, v. 31, n. 1, p. 350-366, 2021.

GUERRA, S. P. S.; OGURI, G.; SCHUMACHER, M. V.; KULMANN, M. S. S.; FARIA, J. I. **Silviculture mechanization index survey: 2022/2023**. Campinas: Instituto de Pesquisas e Estudos Florestais, 2023. 82 p.

GUIMARÃES, D. P. Instruções para a produção de mudas de eucalipto na propriedade rural. **Embrapa Cerrados (CPAC)** – Comunicado Técnico 72, 2014. 6 p.

INDÚSTRIA BRASILEIRA DE ÁRVORES - IBÁ. **Relatório Anual 2023**. São Paulo: IBRE - Fundação Getúlio Vargas, 2023.

KRZESINSKI, J. L. **Influência do preparo do solo no crescimento do eucalipto**: revisão de literatura. 2016. Trabalho de Conclusão de Curso (Manejo Florestal de Precisão) - Universidade Federal do Paraná, Curitiba, 2016. 29 p.

LEMES, P. G.; ZANUNCIO, J. C. **Novo manual de pragas florestais brasileiras**. Montes Claros: Instituto de Ciências Agrárias da Universidade Federal de Minas Gerais, 2021. 996 p.

MAFIA, R. G.; ZARPELON, T. G.; LOUREIRO, E. B.; SILVA, J. B.; SOLIMAN, E. P., SARTÓRIO, R. C.; ZAUZA, E. A. V. **Pragas e doenças do eucalipto**. IPEF, 2023, 176 p.

Bibliography

MANUAL Técnico de Geomorfologia do Instituto Brasileiro de Geografia e Estatística. Rio de Janeiro: IBGE, 2009, 182 p.

MIFSUD, D. *Leptocybe invasa* Fisher & La Salle, 2004 and *Ophelimus maskelli* Haliday, 1844 - two new records of gall forming Eulophidae from Malta (Hymenoptera, Chalcidoidea). **Bulletin of the Entomological Society of Malta**, Mdina, v. 5, p.189-193, 2012.

OLIVEIRA, R.; SERENINE JUNIOR, L.; SOUZA, J. A. G.; SILVA, A. K. V.; SANTOS, M. E. C.; COSTA, L. J.; CUNHA, F. I. U.; MELO, R. R. Seleção de clones de *Eucalyptus* para região norte de Mato Grosso. In: CONGRESSO FLORESTAL BRASILEIRO, 9., 2022, Brasília, DF. **Anais...**p. 251-255, 2022.

OVERBECK, G. E.; VÉLEZ-MARTIN, E.; MENEZES, L. S.; ANAND, M.; BAEZA, S.; CARLUCCI, M. B.; DECHOUM, M. S.; DURIGAN, G.; FIDELIS, A.; GUIDO, A.; MORO, M. F.; et al. Placing Brazil's grasslands and savannas on the map of science and conservation. **Perspectives in Plant Ecology, Evolution and Systematics**, v. 56, 125687, 2022.

PEDOLOGIA. **BDiA**: Banco de Informações Ambientais. IBGE Instituto Brasileiro de Geografia e Estatística. Disponível em: <https://bdiaweb.ibge.gov.br/#/consulta/pedologia>. Acesso em: 20 mar. 2024.

PELLIZZARI, G.; GERMAIN J. F. Scales (Hemiptera, Superfamily Coccoidea). Chapter 9.3. In: Roques A et al. (Eds) Alien terrestrial arthropods of Europe. **BioRisk**, v. 4, p. 475-510, 2010.

PEREIRA, G. S. **Análise da erosão hídrica do solo em plantio de *Eucalyptus benthamii* no município de Otacílio Costa, SC**. 2014. Dissertação (Mestrado em Engenharia Florestal) - Centro de Ciências Agroveterinárias, Universidade do Estado de Santa Catarina, Lages, 2014.

PINCELLI, A. L. P. S. M.; SEIXAS F.; NUNES, R. Compaction and soil fertility after *Eucalyptus* harvesting using feller buncher and skidder. **Cerne**, Lavras, v. 20, n. 2, p. 191-198, 2014.

PRADO, H.; PRADO, T. A. B. **Pedologia fácil**: aplicações em solos tropicais. 6. ed. Produção independente, 2022. 271 p.

QUEIROZ, A. C. M.; RIBAS, C. R.; RABELLO, A. M.; SANTIAGO, G.; LASMAR, C. J.; CANEDO-JÚNIOR, E. O.; ANGOTTI, M.; IMATA, M. M. G. **Produção aliada à conservação no Cerrado: como as formigas podem nos ajudar?** EPTEC, Campina Grande/PB, 2022. 38 p.

RESERVAS DA BIOSFERA, **Reserva da Biosfera da Serra do Espinhaço (RBSE)**, UNESCO. Available at: <https://reservasdabiosfera.org.br/reserva/rb-serra-do-espinhaco/>. Accessed 26 April,

Bibliography

REZENDE, B. S. M. **Levantamento das doenças bióticas e abióticas na cultura do eucalipto no estado de Mato Grosso**. 2016. Trabalho de Conclusão de Curso (Engenharia Florestal) - Universidade Federal de Mato Grosso, Instituto de Ciências Agrárias e Ambientais, Sinop, 2016. 77 p.

RUDEK, A.; GARCIA, F. A. O.; PERES, F. S. B. Evaluation of seedlings quality from the leaf area of *Eucalyptus grandis* seedlings from the use of digital images. **Enciclopédia Biosfera**, Goiânia, v. 9, n. 17, p. 3775-3787, 2013.

SANTAROSA, E.; PENTEADO JUNIOR, J. F.; GOULART, I. C. G. R. **Transferência de tecnologia florestal: cultivo de eucalipto em propriedades rurais: diversificação da produção e renda**. Colombo: Embrapa Florestas, 2014. 138 p.

SANTOS, H. G. **Sistema brasileiro de classificação de solos**. 5. Brasília/DF: Embrapa, 2018. 356 p.

SANTOS, P. E.T.; PALUDZYSZYN FILHO, E.; MAGALHAES, W. L. E.; BEN, T. J.; MOREIRA, S. Melhoramento genético de eucaliptos subtropicais: contribuições para a espécie *Eucalyptus benthamii*. **Embrapa Florestas**, Colombo/PR, s. 347, 2020, 85 p.

SCHUMACHER, M. V.; VIEIRA, M. **Silvicultura do eucalipto no Brasil**. Santa Maria: Ed. UFSM, 2016. 308 p.

SILVA, P. H. M.; VIEIRA, I. G.; MENDES, J. C. T.; ARAUJO, M. J.; MOREIRA, R. M. **Recursos Genéticos de Eucalipto nas Estações Experimentais de Ciências Florestais da ESALQ: Usos e Manutenção**. IPEF, Piracicaba/SP, 182p, 2023. 82 p.

SILVA NETO, E. C.; ANJOS, L. H. C.; CALEGARI, M. R.; HORAK-TERRA, I.; OLIVEIRA, F. S.; VALLADARES, G. S.; SOUZA, J. J. L. L.; PEREIRA, M. G. **Organic soils in Southeastern Brazilian highlands: formation and relations to vegetation history**. **Catena**, Amsterdam, v. 237, art.107786. 2024.

STEFANUTO, E. B.; LUPINACCI, C. M.; CARVALHO, F.; FRANCOS, M.; UBEDA, X. An evaluation of erosion in cuesta relief: São Paulo State, Brazil. **Geomorphology**, 108049, 2022.

TÓTH, T.; GALLAI, B.; NOVÁK, T.; CZIGÁNY, S.; MAKÓ, A.; KOCSIS, M.; ÁRVAI, M.; MÉSZÁROS, J.; LÁSZLÓ, P.; KOÓS, S.; BALOG, K. Practical evaluation of four classification levels of Soil Taxonomy, Hungarian classification and WRB in terms of biomass production in a salt-affected alluvial plot. **Geoderma**, Amsterdam, v. 410, art. 115666, 2022.

WENDLING, I.; DUTRA, L. F.; GABIRA, M. M.; VIEIRA, L. M.; DEGENHARDT, J. Produção de mudas de eucalipto. In: OLIVEIRA, E. B.; PINTO JUNIOR, J. E. (eds.). **O eucalipto e a Embrapa: quatro décadas de pesquisa e desenvolvimento**. Brasília/DF: Embrapa, 2021. cap. 22, p. 823-857.

Overview of eucalypt plantation in Brazil

ISBN: 978-65-89571-14-8



NELSON MANDELA
UNIVERSITY

