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# Citrus Industry in Brazil with Emphasis on Tropical Areas

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Additional information is available at the end of the chapter

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## Abstract

This chapter is a review on citrus-producing areas in Brazil with emphasis on the tropical zone. Considering the degrees of latitude, the citrus industry can be classified into four major regions: (1) South, represented by the State of Rio Grande de Sul with temperate climate; (2) São Paulo, Minas Gerais and Paraná States in the central part of the country, where the major citrus-processing industries are established under subtropical conditions; (3) Amazon basin, the northern part of Brazil around the Equator; and (4) Northeast, the typical tropical region. For each region, data are presented as to the geographical position, climate and soils, area harvested production volume and yield. A strong climatic influence on fruit quality can be observed. There is a tendency for fruits to be smaller in size, but with a longer maturation and life periods on the trees, as they are produced at increasing distances from the equator.

**Keywords:** climate, latitude, scion and rootstock cultivars, fruit quality

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## 1. Introduction

The history of the citrus industry in Brazil is intimately linked to its own history. Sweet orange seeds were introduced by the Portuguese jesuits 30 or 40 years after the discovery of Brazil (1500), in the States of Bahia and São Paulo. Due to favorable ecological conditions, the trees

(as seedling) produced quite well. The activity remained unknown until the nineteenth century when, during the colonial period, the fruits of the 'Bahia' ('Washington Navel') orange, originated in the Bahia State, were recognized by the Portugal reign as being larger and juicier than those produced in that country. More important fact, however occurred after its introduction in California it was recognized as 'more important as the gold extracted from the soils of the Golden State' and considered as responsible for the development of the citriculture in the five continents. Nevertheless, only in the 1930s, the citriculture began to be implanted commercially in States of São Paulo, Rio de Janeiro and Bahia, with greater growth rate in the states of the Southeast. This chapter is a review on the Brazilian citriculture focusing the four main citrus poles (**Figure 1**) with their respective producing states and geographical locations, climate, harvested area, production and yield.



**Figure 1.** Map of Brazil with the physiographic regions and the main citrus poles. (1) South, represented by the State of Rio Grande de Sul (temperate climate), (2) São Paulo, Minas Gerais and Paraná States (central part of the country), (3) Amazon basin, represented by the States of Amazonas and Pará (equator region) and (4) Northeast, represented by the States of Bahia and Sergipe (typical tropical region).

## 2. Main citrus poles

There are no climatic limitations for citrus growing in Brazil. Irrigation is not necessary, except in the semiarid areas of the Northeast, where the rainfall is below 700 mm and in the south where frosts can occur. The altitude varies from 20 to 500 m. Rainfall varies from 1,000 to 1,800 mm, during the winter in the Northeast (March–August) and in the summer in the Southeast (September–March). In Rio Grande do Sul, the rainfall is almost monthly. The relative humidity is higher in the Northeast, where in the winter it almost reaches 100%, with the annual average being between 75 and 80%. The annual average temperature varies from 19°C in the South to 25°C in the Northeast. Independent of the area, flowering occurs in September, one or more times depending on the distance to equator. The farther from the equator, smaller are the fruits but they stay on the trees longer. The soils of the citrus-growing areas are sandy/loam, deep, well drained, but with poor fertility especially in phosphorous. Except the shallow soils of some areas, like the cocoa-growing area in Bahia, the humid Amazonian area or the loamy areas of the States of Paraná and São Paulo, where the coffee and the sugarcane are cultivated, there is an immense area which is available to the citrus industry in Brazil. In an analysis on the Brazilian territory (8.5 millions square meters), it would be possible to adopt a classification of the citriculture on four main citrus poles which are described as follows.

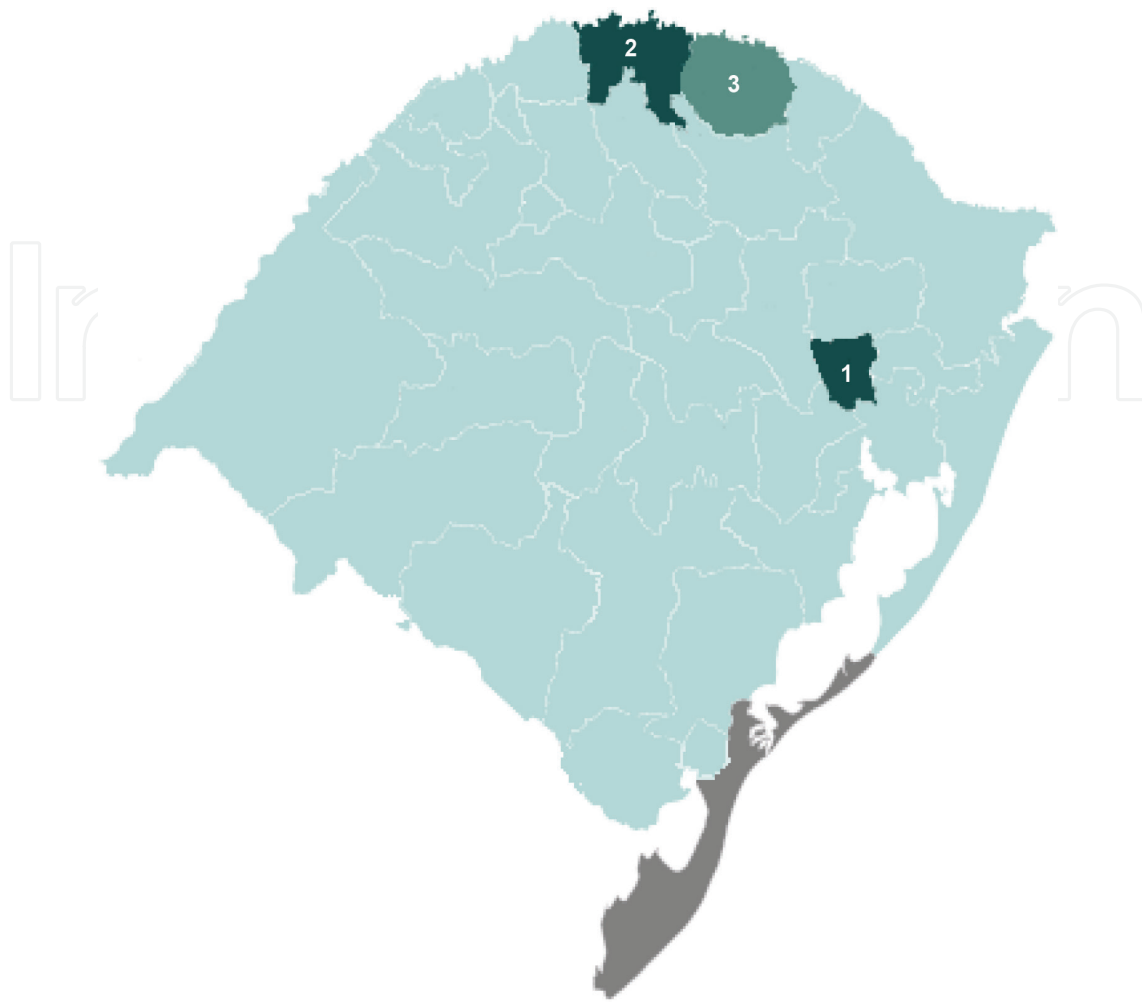
### 2.1. Citrus belt in the south region

The citrus production in the South of the country is represented by the State of Rio Grande do Sul, which is achieved in 2016, 553,372 tonnes, being the largest concentrations of sweet orange (71.5%) and mandarin (25.4%) [8].

There are 35 microregions in the State of Rio Grande do Sul, 34 of them produce citrus (**Figure 2**). The regions that most stand out are: Montenegro, Frederico Westphalen and Erechim. The microregion of Montenegro has its production concentrated in orange (45.8%) and mandarin (47.0%) and only 7.2% in lemon. The most important counties are Montenegro, Harmonia, Pareci Novo, Tupandi and São José do Hortêncio. From these, Montenegro highlights the production of mandarin. The second most important microregion is Frederico Westphalen, whose participation in the production was 91.9% of orange, 7.1% of mandarin and 1.0% of lemon. From the 27 remaining countries that compound the microregion, only 3 deserve special mention: Liberato Salzano, Planalto and Alpestre. The microregion Erechim comes next and it is composed of 30 counties, the most important ones being Aratiba, Itatiba do Sul and Mariano Moro.

#### 2.1.1. Climatic characterization

In the State of Rio Grande do Sul, the latitudes varies from 27°14'56" S in Alpestre to 30°53'27" S in Santana do Livramento do Sul near to Uruguay. Longitudes varies from 53°02'06" to 55°31'58" W in the same municipalities. Annual media temperature varies from 19.8 to 18.4°C and the rainfall from 1,892 to 1,467 mm in the same municipalities. The climate of the State of Rio Grande do Sul is humid subtropical (or temperate). It is constituted by four reasonably



**Figure 2.** Concentration of the citrus production in Rio Grande do Sul in the principal microregions. Source: [8]. Obs.: Dark color means data not available.

well-defined seasons, with moderately cold winters and hot summers (mild in the higher parts), which are separated by intermediate seasons of approximately 3 months of duration and rains well distributed along the year. Due to its latitudinal situation (inserted in the context of the average latitude), Rio Grande do Sul presents peculiar features different from the climate of the rest of Brazil. The temperatures of the state, in diverse regions, are among the lowest ones of the Brazilian winters, reaching 6°C in cities like Bom Jesus, São José dos Ausentes and Vacaria, where frequent frosts and occasional snowfall happen, and where it is not recommended in the planting of citrus. There are still the altimetric differences, with special feature for Serra do Sudeste and Serra do Nordeste, which is not recommended for planting of citrus because of the high frequency of frosts. During autumn and winter, the state is also liable to the summer phenomenon, which consists of a succession of days with not normal high temperatures for the season. Different from the other states of Brazil, the occurrence of heavy frosts is relatively strong in the whole state demanding the usage of rootstock tolerant to cold.

### 2.1.2. Production characterization

The citriculture of the State of Rio Grande do Sul comprehends an almost complete chain, involving around 20,000 farmers, more than 100 nurserymen, producers of various inputs,

beneficiators of fruit, industries of concentrated and ready to drink juices and of others byproducts of the fruit, wholesalers, marketers, retailers and around 11 millions of consumers. The annual production of orange is 396,000 tonnes (24,000 ha), of mandarin is 141,000 tonnes (11,000 ha) and of acid limes and true lemons is 17,000 tonnes (1,400 ha), being the state, respectively, the sixth, the fourth and the sixth greatest national producer of these fruits [8]. Even so, Rio Grande do Sul imports from others states, especially from Paraná and São Paulo, and from others countries, principally from Spain and Uruguay, almost 50% of the citrus which consume fruit and juice. The vast majority of the citrus growers is family-based, being the average planted area with citrus beneath two hectares per property. The business citriculture is conducted by less than a hundred producers located mainly in the regions of Vale do Caí and Campanha Gaúcha, with the cultivated area of 3–300 ha per property. The associativism is very practiced in Rio Grande do Sul, notably in Vale do Caí, where with the small citrus growers seek to overcome their limitations of production, mostly in the processing and in the marketing of the fruit. The principal poles of production are found in Vale do Caí, Campanha Gaúcha and in the northwest region of the state. The citriculture of the Vale do Caí exists for three generations, standing out, nowadays, for the production of mandarins. In the northwest region, the citriculture is much more recent and its expansion was supported by Emater – RS, it concerns small orchards where the orange tree Valência is primarily cultivated and good part of the fruits is destined to the industrial process. In the Campanha Gaúcha region, the production pole of seedless citrus is found. It was initiated in 1998 with the support of Embrapa Clima Temperado, where it is cultivated approximately 2500 hectares and the production is marketed in the principal supermarket network of the state and in others parts of the country. For cultivars, the region of the Vale do Caí detaches in the production of Montenegrina (principal), Caí and Pareci mandarins; the northwest region in orange tree Valência (principal) and Folha Murcha; and the Campanha Gaúcha in navel orange tree Navelina, Lane Late and Cara Cara (**Figure 3**), orange tree Salustiana, mandarin tree Okitsu and hybrids Ortanique and Nadorcott (**Figure 4**) and other varieties (**Figure 5**). The Trifoliata is the principal rootstock used, highlighting itself by the longevity of the plants, the tolerance to various diseases and to induce the high quality of the fruits. The system of conventional production is used in the great majority of citric properties. However, there are more than one hundred of organics products and practically the same number using the principles of integrated production. Among the main limitations of the culture, the phytosanitary nature ones are bounced. According to the producers, the black spot disease is outstandingly the biggest problem of the region of the Vale do Caí, followed by the citrus canker and by the brown spot of alternate. These two last diseases have been controlled especially by the usage of tolerant cultivars. The black pint and the brown spot of alternate do not exist up to the moment in the region of the Campanha Gaúcha, where the citric canker is the major limiting factor. These disease is endemic in the larger part of Rio Grande do Sul and it causes great losses notably in the rainy season. The handling of the disease has been conducted by means of spraying copper-based products and specific cultural practices to reduce source of inoculum. The Huanglongbing (HLB) has not been found in Rio Grande do Sul yet, according to the annual lifting accomplished by the Ministério da Agricultura, Pecuária e Abastecimento (MAPA) in partnership the Embrapa Clima Temperado. However, the vector insect exists in some regions. Although there are around 10 juice and citrus byproducts industries, the production is directed mainly to the market of fresh fruits, prioritizing the state demand.





**Figure 3.** 'Cara Cara' (navel) sweet orange in Rio Grande do Sul, the first producing Brazilian state for fresh consumption. Source: Roberto Pedroso.



**Figure 4.** Harvesting of 'Nadorcott' mandarin in Rio Grande do Sul. Source: Roberto Pedroso.



**Figure 5.** 'Nova' tangelo and 'Meyer' lemon in Rio Grande do Sul. Source: Roberto Pedroso.

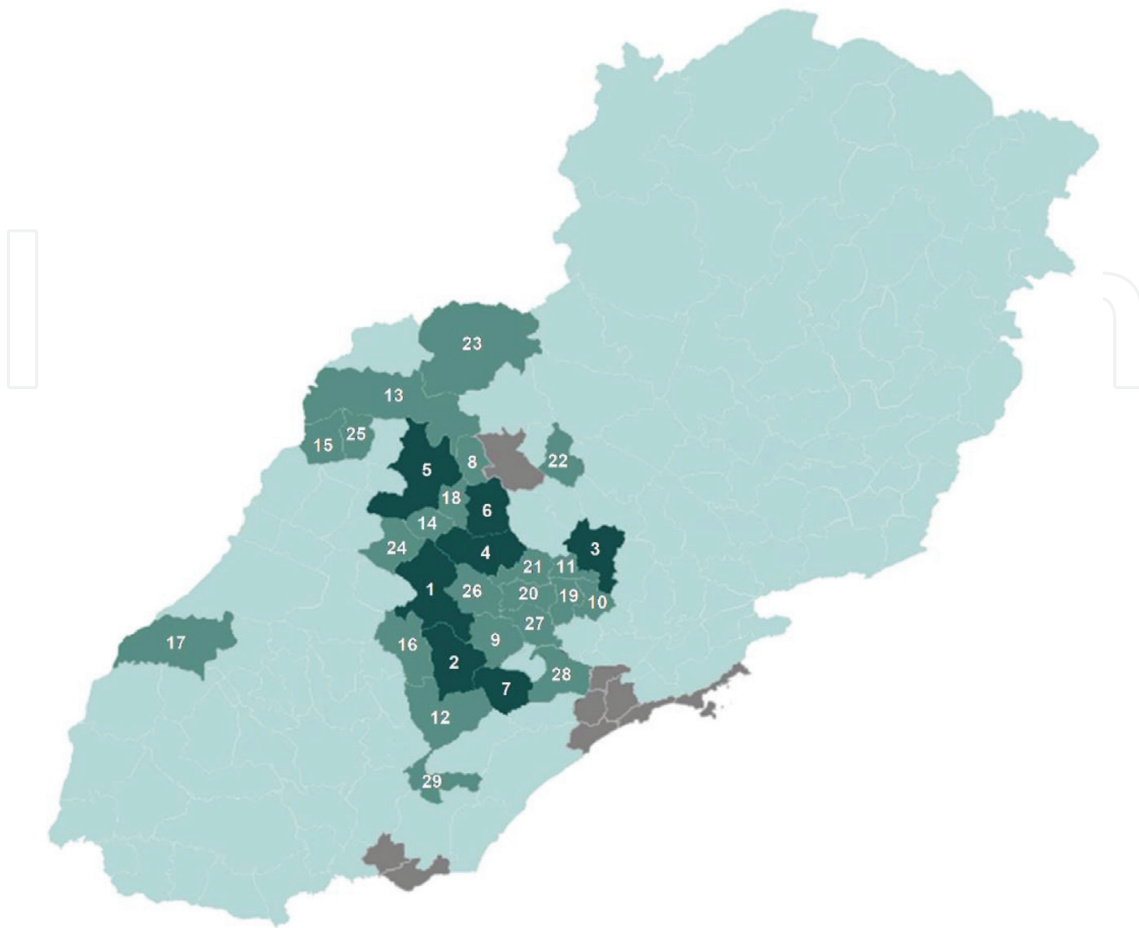
## 2.2. Citrus belt in São Paulo, Minas Gerais and Paraná states

The production of citrus in the principal citrus pole of the country encompasses the States of Minas Gerais, São Paulo and Paraná. The production from São Paulo, the most expressive one, is distributed in sweet orange, lemon and mandarin, with volumes of 12.8 million, 875,000 and 345,000 tonnes in 2016, respectively, in order of importance. In the State of Minas Gerais, the citrus production achieved 1,258,767 tonnes being 80% of orange and 13% of mandarin and 7% of lemon. The State of Paraná produced 922,422 tonnes of citrus—80% of orange and 20% of mandarin [8]. There are 63 microregions in the State of São Paulo, and from these, 25 microregions are the most important in the citrus production (**Figure 6**). Of these 25, the highest concentrations are in 7 microregions, in order of importance: Bauru, Avaré, São João da Boa Vista, Araraquara, São José do Rio Preto, Jaboticabal and Itapetininga. Lower concentrations occur in 18 microregions: Barretos, Botucatu, Mogi Mirim, Pirassununga, Itapeva, Novo Horizonte, Jales, Ourinhos, Catanduva, Limeira, Rio Claro, São Carlos, Franca, Lins, Fernandópolis, Jaú, Piracicaba and Sorocaba. Although Minas Gerais owns 66 microregions, just 2 of them stand out in the production of citrus: Frutal and Uberlândia. Both of them are part of the Triângulo Mineiro and in 2016 they produced about 414,000 and 259,000 tonnes, respectively. In the microregion of Frutal, the most important counties are Comendador Gomes and Frutal, while in the microregion of Uberlândia the counties that most highlight are Prata, Uberlândia and Monte Alegre de Minas. There are 39 microregions in Paraná, of which only 2 do not produce citrus. The two most important microregions in the citrus production are Paranavaí and Cerro Azul. Both microregions produce citrus, but Paranavaí presents the greatest volume in the orange production (99.4%) and Cerro Azul calls attention in the mandarin production (92.4%). The microregion of Paranavaí owns 29 counties, of which 9 do not produce any kind of citrus and the 3 that more stand out are Paranavaí, Guairaçá and Alto Paraná. In the microregion of Cerro Azul, two counties highlight, Cerro Azul and Doutor Ulysses, both of them concentrate their productions to the mandarin fruit.

### 2.2.1. Climatic characterization

Citrus trees are cultivated in São Paulo State often under mountain subtropical climate, that is, Cwa according to Köppen's classification. Considerable areas are in Cfa climate, and minor cultivation is carried under Aw and Cfb climates, respectively, on the coast and in the highlands. Considering Cwa as the prevalent condition, climate is characterized with hot, rainy summers, and dry, relatively cold winters. Two main climate types for citrus cultivation could be described: (i) mean annual air temperature higher than 17°C and annual water deficit of 0–60 mm and (ii) mean annual air temperature higher than 17°C and annual water deficit higher than 60 mm [16]. Minimal air temperatures are in the range of 8–10°C, and maximum can surpass 40°C. Annual rainfall ranges from 1,000 to 2,000 mm, often 1,400–1,800 mm, with distribution concentrated from November to March. Altitude ranges from 400 to 1000 m, but 550–750 m is prevalent. Citrus areas are free of severe frosts in São Paulo, even though it is regularly observed in the South of the State and in Paraná. Prolonged drought is frequent, especially on the North of São Paulo and in Minas Gerais State, as drought intensity decreases with the latitude. In recent years, heat stress associated to drought was reported in the main citrus areas in September–October, which is the period of the main blossom and fruit set.





**Figure 6.** Concentration of the citrus production in the states of Minas Gerais, São Paulo and Paraná, concerning the principal microregions. Source: [8]. Obs.: Dark color means data not available.

### 2.2.2. Main producing areas

The citrus belt comprises the Northwest of Paraná State ( $23^{\circ}04' \text{ S}$ – $52^{\circ}27' \text{ S}$ ); the Triângulo de Minas Gerais region ( $19^{\circ}18' \text{ S}$ – $48^{\circ}55' \text{ S}$ ) and São Paulo State ( $21^{\circ}49' \text{ S}$ – $49^{\circ}12' \text{ S}$ ), which is divided in the following areas (as percentage of the total citrus area in this state): North (22%), Northwest (11%), Center (29%), South (20%) and Southwest (18%) [16].

### 2.2.3. Scion and rootstocks varieties

São Paulo, Minas Gerais and Paraná had about 430,000, 38,000 and 25,000 ha of sweet orange groves in 2016–2018, respectively [5, 6]. The main varieties are, in decreasing order, Pera (mid-season), Valencia (late), Hamlin (early), Natal and Folha Murcha (both late) and the early season varieties of Valencia Americana, Westin and Rubi, although the former four comprise more than 80% of the total trees. Some other varieties including navels and acidless oranges are cultivated in smaller areas. Persian lime and lemons are also cultivated mainly in São Paulo (39,000 ha in 2018), and mandarins, largely Ponkan mandarin and Murcott tangor, are important for all states (12,000; 8,000 and 10,000 ha for São Paulo, Minas Gerais and Paraná, respectively). Sweet oranges are produced mainly for juice processing, and the citrus belt represents more than 85%

of the Brazilian production. This is the most important orange production area in the world (34%) resulting in 56% of the juice produced and 76% of the marketed in the world [11]. Almost 97% of the juice is exported, while mandarins are for fresh fruit in the internal market, and limes and lemons are for fresh fruit and few processing, and exportation of fresh fruit too. Rangpur lime was the most used rootstock until the 2000s, as a result of its tolerance to both citrus tristeza virus (CTV) and drought, high and early yield, and great vigor and graft compatibility in the nursery. However, it is sensitive to citrus sudden death (CSD), blight, citrus nematode and gummosis of *Phytophthora* spp., and induces low juice quality, therefore after 2000, it has been increasingly replaced by the Swingle citrumelo. This rootstock is tolerant to all mentioned diseases. Despite being sensitive to drought, it induces high production of high quality juice [13]. Sunki mandarin is currently the third most used rootstock, especially for Pera since this scion in addition to Murcott and some selections of lemons are graft-incompatible with Swingle citrumelo. Cleopatra mandarin, trifoliolate orange and Flying Dragon are used in a smaller amount. The Tropical selection of Sunki mandarin and a few citrandarins are been tested and used in increasing areas being considered promising rootstocks for the orchard diversification.

#### 2.2.4. Other information

The citrus industry in São Paulo, Minas Gerais (**Figure 7**) and Paraná (**Figure 8**) employs more than 200,000 people and contributes with US\$ 6.5 billion annually. Although about 6,000 farms cultivate oranges, 88% of the growers have less than 50,000 trees, while 12% of farms with more than 100,000 trees correspond to 77% of the total trees (194 millions) [6]. Therefore, the citrus cultivation in the citrus belt is nowadays a highly intensive, technological entrepreneurial activity. However, harvesting and fruit transportation reaches almost 50 of the production cost (**Figure 9**). Nursery stocks have been grown in insect-proof screen houses since 2003, and about 10 million grafted trees are produced annually in pots filled with potting media. Orchards use currently an average of 484 trees/ha, but new groves increased tree density to 656 trees/ha in average. About a third of the area is currently irrigated, and major cultivated area corresponds to trees from 5 to 15 years old. Citrus diseases and pests are major limiting factors to the citrus industry of the three states that substantially increase the



**Figure 7.** Ponkan mandarin orchard in Minas Gerais. Source: Eduardo Girardi.



**Figure 8.** Planting of citrus in Paraná. Source: Eduardo Girardi.



**Figure 9.** Harvesting of sweet orange in São Paulo, the first citrus-producing state in Brazil. Source: Eduardo Girardi.

production costs. Huanglongbing (HLB) is the most devastating one, and the average incidence in São Paulo and Triângulo de Minas Gerais was about 17% in 2017 [7]. The smaller the farm, the higher the incidence, because HLB management essentially depends on the eradication of symptomatic trees and on the control of the vector, the Asian citrus psyllid, in addition to control measures on inoculum sources outside the farm. As a result, management is more efficient if taken by all growers in an area wide approach. Other important phytosanitary problems include black spot, citrus canker, leprosis virus, citrus variegated chlorosis, citrus sudden death, post bloom fruit drop (*Colletotrichum acutatum* and *C. gloeosporioides*), *Alternaria* brown spot of mandarins, fruit flies, mites and scales.



### 2.3. Citrus belt in the north region (Amazon basin)

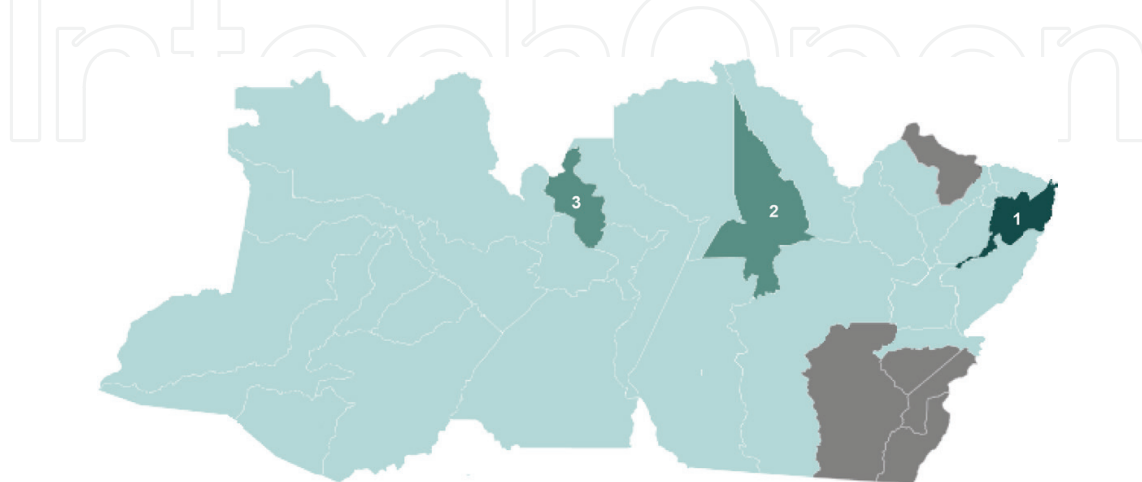
Considering the enormous area of Northern Brazil, citriculture is poorly exploited in this region, with the States of Pará and Amazonas showing the highest productions. From 270,370 tonnes of sweet orange, 53,806 tonnes of acid lime and 4,722 tonnes of mandarin, the State of Pará is responsible for 70.8% of sweet orange, 73.9% of acid lime and 20.9% of mandarin, while in the State of Amazonas these values are 14.9, 4.2 and 6.7%, respectively. Cultivated area comprises only 19,515 ha with the following distribution: 15,876 ha of sweet oranges, 3,054 ha of lemons/limes and 585 ha of mandarins. Average yield in these states is 14.1 t/ha indicating that the regional yield is about 54.6% of the national average (25.8 tonnes/ha).

#### 2.3.1. Concentration of the production

All states in the North of Brazil produce citrus. However, Pará and Amazonas are highlighted once contribute with 70.6 and 13.0%, respectively, of the regional production, and these states rank in seventh and thirteenth position among Brazilian citrus-producing states. There are 22 microregions in the State of Pará, but citrus is cultivated in 17 of them. In this state, the two main citrus-producing areas are Guamá and Santarém. The former has the major concentration of citrus crops (sweet orange, lime/lemon and mandarin) (**Figure 10**). In the Guamá area, the greatest producer is the municipality of Capitão Poço, most notably with oranges, while in the Santarém area the production of lemon/lime is more important in the municipalities of Monte Alegre and Alenquer. The State of Amazonas has 13 microregions, and citrus production is mainly sweet orange cultivated in the Rio Preto da Eva microregion in the municipality with the same name.

#### 2.3.2. Climatic characterization

The North region consists of the largest part of the Amazon Basin and it is characterized by low altitudes between 0 and 200 m. The climate is tropical equatorial with predominance of the type Af in the States of Amazonas and Acre, and of the type Am in the States of Pará,



**Figure 10.** Concentration of the citrus production in the States of Amazonas and Pará, concerning the principal microregion. Source: [8]. Obs.: Dark color means data not available.

Amapá, Roraima and Rondônia. Only the State of Tocantins presents the climate type Aw. Atmospheric circulation systems, in the intertropical convergence zone, are responsible for the climate variability and for the rains in the state of the Amazon Basin. The average annual precipitation exceeds 2,000 mm, as until 3,000 mm in the estuary of the Amazonas River in Belém, and 2,400 mm in the innermost region of the Amazon Basin, in Manaus. In the direction of Roraima, East of Pará, there is less rainfall, with the annual total in the order from 1,500 to 1,700 mm. The rainy season in the greatest part of the region comprehends the period from December to May. During the rainiest months, March and April, precipitations of up to 400 mm monthly are reached. The 'dry season' from June to November still shows precipitations of 60–120 mm per month. Unlike, in the State of Roraima, due to the influence of the climatic conditions from the North hemisphere, the maximum rainfall indices occur in the period from April to September, with a longer dry season between October and March. Concerning the temperatures, the predominant climate is hot, with average annual temperatures varying from 22 to 28°C, average temperature of the coldest month of 18°C and maximum of 42°C in the hottest months. The temperatures are high in most of the region with low thermal amplitude except in some locals of higher altitude in Roraima and in Acre. In Rondônia, due to the entrance of cold air masses from the Atlantic Ocean, passing by the State of Mato Grosso, temperatures are reduced causing the phenomenon of 'coldness' for short periods of 5–6 days.

### 2.3.3. Production characterization

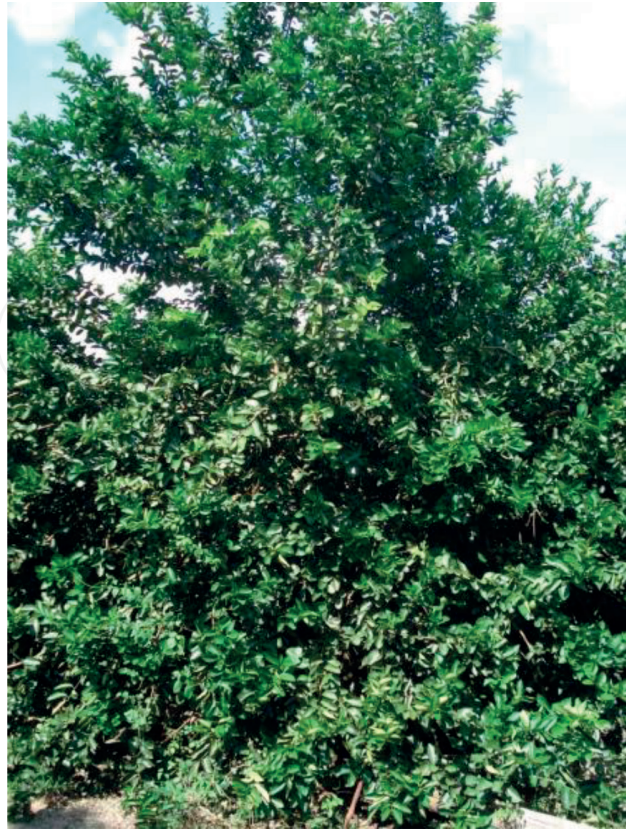
#### 2.3.3.1. Citriculture in State of Pará

Considered as the largest citrus pole in the equatorial zone (Amazon basin), the citriculture of Pará is represented by the municipality of Capitão Poço in an area of 11,000 of hectares [4]. The fruit production, made by at least 1,000 growers, is destined for other states including for juice processing plants. It is reference as organic orange producer, being 70% of family farming, and the municipality restarted its certification process [9]. Different as compared to other producers in Brazil, the harvesting season occurs from September to December with a minor harvest in March and April. As in the Northeast region, the combination scion/rootstock cultivated is 'Pera' sweet orange × 'Rangpur' lime and the yield of orange and acid lime is very low, around 15 tonnes per hectare per year.

#### 2.3.3.2. Citriculture in State of Amazonas

**Oranges:** in the orchards of the North region, there is a predominance of the 'Pera' sweet orange variety (**Figure 11**), even though some farmers produce the 'Valencia' in small scale. In spite of the good productivity and of the uniformity in fruit size of the 'Valencia', in the States of Amazonas and Roraima, there is a consensus among the producers in refusing this variety claiming that there is no market space for it. In smaller proportions, there are orchards with the 'Folha Murcha' variety. **Mandarins:** 'Murcott' and BRS Piemonte tangors and 'Mexerica do Rio' Mediterranean mandarin are the most commons in the North region. 'Tahiti' acid lime, especially the IAC-5 and 'Quebra Galho' clones, were initially used, and later substituted by the 'CNPMPF 2001' clone. Although there are appropriate conditions, the productivity of mandarin is low. **Rootstocks:** since the period of the introduction of the citriculture in the





**Figure 11.** Big 'Pera' sweet orange tree in Amazonas. Source: Luciano Souza.

North region, the rough lemon, the 'Cleopatra' mandarin and the 'Rangpur' lime were used as rootstocks, being the last one the predominant in the regional orchards nowadays. In smaller proportion, we still may find 'Cleopatra' mandarin orchards formed 15 years ago. 'Rough' lemon, in small scale, has been used by some growers as rootstock. 'Swingle' citrumelo has just been used grafted with the 'Tahiti' acid lime. As a characteristic of equatorial conditions,



**Figure 12.** 'Pera' sweet orange fruits in Amazonas. Source: Luciano Souza.

the 'Pera' sweet orange in the Amazon region presents greenish fruits even in the maturation period, although it presents the relation Brix/acidity and pulp coloration adequate to the consumption (**Figure 12**).

## 2.4. Citrus belt in the northeast region

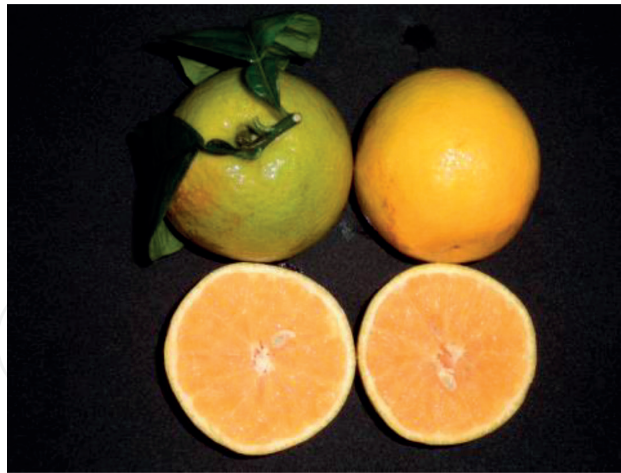
Sweet orange, lime and mandarin fruits are being produced in the states of the Northeast region, however the States of Alagoas, Pernambuco and Piauí do not produce mandarin. From the nine Northeastern States, Bahia and Sergipe stand out, with 66.2 and 26.1% of the regional production, and second place in the national production. From 1,744,673 tonnes of sweet orange, 169,123 tonnes of acid lime and 34,247 tonnes of mandarin, the State of Bahia is responsible for 64.8% of sweet orange, 88.1% of acid lime and 30.0% of mandarin, while in the State of Sergipe these values are 28.0, 4.9 and 30.3%, respectively. In these states, the citriculture occupies an area of 127,517 ha as follows: sweet orange 118,473 ha, acid lime 7,769 ha and just 1,275 ha with mandarin. The yield average is very low, just 14 tonnes/ha, representing almost half of the national average.

### 2.4.1. Climatic characterization

The Northeast region is located between 2 and 18° South latitude and 35° and 50° West longitude. The climate along the sea coast is hot and humid (tropical), with annual temperature average varying between 20 and 28°C and rainfall between 300 and 2,000 mm. The sunshine time varies from 2,300 per year in the humid areas up to 3,000 in the semiarid areas. The largest area in the Northeast is under semiarid conditions ('Polígono das Secas')—less than 750 mm of rain per year), The region comprises nine states: Maranhão, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe and Bahia, that occupies 18.2% of the national territory. Analyzing the regions and its ecological diversity, in relation to the citrus trees, it is possible divide them in three grand zones: (1) sea coast (Coastal Tablelands) represented by the municipality of Cruz das Almas (BA); (2) area of altitude, represented by the municipality of Morro do Chapéu—Chapada Diamantina (BA), over 1,000 m of altitude and (3) semiarid zone, represented by the municipality of Petrolina (PE).

### 2.4.2. Production in traditional areas

The sea coast (Coastal Tablelands) is located along the sea, near the main capitals. The relative humidity is high and rainfalls around 1,000 mm per year but very concentrated during the summer time (December–March). Under these conditions, it predominates the sweet orange group represented almost exclusively by 'Pera' sweet orange (**Figure 13**), which fruit quality is typical in the tropical areas: larger fruits, juicier, less colored and less acid than those produced under subtropical conditions. More recently, the 'monocitriculture' of 'Pera' sweet orange × 'Rangpur' lime rootstock (almost 100% of the orchards) has been broken by the use of 'Tahiti' acid lime, unfortunately on the same rootstock. The fruit production destination is divided between the fresh fruit market and for processing (frozen concentrated juice). For a long time, Embrapa is stimulating the scion and rootstock diversification recommending as early varieties: 'Rubi', 'Westin' and 'Salustiana'; midseason: 'Pineapple', 'Pera' and 'Sincorá'; late: 'Natal', 'Valencia' and 'Folha Murcha' (Curled Leaf) [1], as well the following rootstocks: 'Indio', 'Riverside' and



**Figure 13.** ‘Pera CNPMF D-6’ sweet orange in Bahia – The most popular variety in Brazil. Source: Orlando Passos.

‘San Diego’ citrandarins (from USDA), ‘Sunki Tropical’ mandarin and ‘Santa Cruz Rangpur’ lime. News rootstock hybrids are being released by the Embrapa Citrus Genetic Improvement Program [15] due to traditional areas that represent the Northeastern citriculture, the analyses on fruit productions will be concentrated in the States of Bahia and Sergipe. In Bahia, there are 32 microregions but only 4 can be considered as citrus producer: Alagoinhas, Santo Antonio de Jesus, Ribeira do Pombal and Entre Rios (**Figure 14**). From these, the first presents the largest citrus concentration represented by the municipalities of Rio Real, Inhambupe and Alagoinhas. In the Santo Antonio de Jesus microregion, sweet orange, acid and sweet lime and mandarin fruits are produced in the municipalities of Cruz das Almas, Sapeaçu, Muritiba, Governador Mangabeira and Cabaceiras do Paraguaçu as the most important. In Cruz das Almas, the largest participation comes from acid lime designated to the exporting market. Ribeira do Pombal microregion is concentrated just on sweet orange production and is located in a climatic transition zone which rainfall is less than 1,000 mm. The most important municipality is Itapicuru and its neighbors where exist the most appropriate conditions in the State for the citrus expansion, due to the existence of Tucano aquifer. In Entre Rios microregion, sweet orange production is concentrated in the municipalities of Esplanada and Jandaíra. In Sergipe State, there are 13 microregions being the most important, in a descending order, Boquim, Estância and Agreste de Lagarto. The Boquim microregion is most important in the production of sweet orange, mandarin and limes mainly in the municipalities of Itabaianinha, Cristinápolis, Salgado, Boquim, Arauá, Umbaúba and Tomar do Geru. In the microregion Estância, similarly, the citrus production is concentrated in the same groups. The main municipality producers are Santa Luzia do Itanhy, Estância and Indiaroba. Finally, Agreste de Lagarto microregion is predominated with the sweet orange and mandarin, mainly in the municipalities of Lagarto and Riachão do Dantas.

### 2.4.3. Production in potential areas

#### 2.4.3.1. Altitude zone

It is located in the States of Bahia, Pernambuco, Paraíba and Ceará with milder climate, low temperatures in the winter (July is the coldest month), and insufficient rainfall for the culture



**Figure 14.** Concentration of the citrus production in the states of Bahia and Sergipe, considering their microregions. Source: [8]. Obs.: Dark color means data not available.

necessity, what requires complementary irrigation. Inside this ecosystem is the Chapada Diamantina tableland, whose altitude varies between 1,000 and 1,400 m. In this zone, the table fruits should be prioritized, preferably the mandarins without despising the seedless navel oranges ('Bahia' sweet orange). Among these fruits, some stand out: 'Cara Cara' ('Bahia' of red pulp), 'Baianinha' (little Navel) and 'Lima' (no acidity). In the mandarins group, beyond the traditional 'Ponkan' and 'Murcott', special attention should be given to the tangelo mandarin tree 'Page' (seedless fruit, in isolated plantation), to the tangor mandarin tree 'Piemonte' (Figure 15) and to the BRS Salibe Murcott (fruits with few seeds).

#### 2.4.3.2. Semi-arid zone

The Brazilian semi-arid is an ecoregion defined from the isoieta of 800 mm. The climate can be classified, according to Köepen, as type BswH, which corresponds to a very hot semi-arid region. The annual rainfall index is 571.5 mm with concentration from December to March [2]. The average annual temperature is 26.4°C, with average minimum of 20.6°C, and with average maximums of 31.7°C. The daily thermal amplitude is around 10°C, monthly of 5–10°C and annually from 1 to 5°C; very strong insolation (annual average of 2,800 h/year);





**Figure 15.** 'Piemonte' mandarin-tangor in Bahia—A new variety for fresh consumption. Source: Orlando Passos.

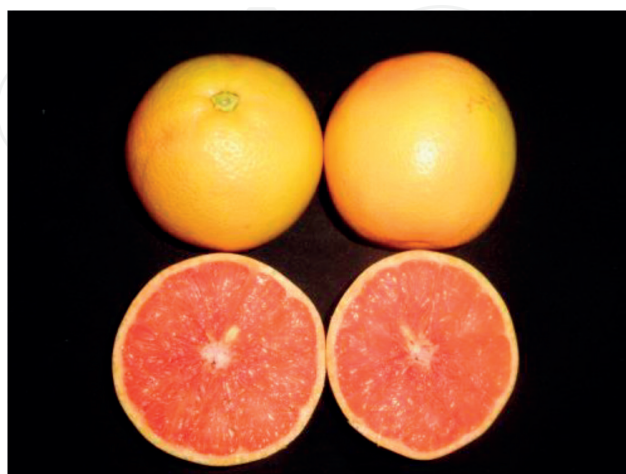
low relative humidity (annual average around 50% per year); and high evapotranspiration (average of 2,000 mm/year) [10, 14]. In areas of hot or tropical climate, like in the Northeast region, the amplitude is smaller, what implies in the fruit production of less coloring, not just inside but also outside. However, the contents of soluble solids ( $^{\circ}$ Brix) are higher and present low acidity, resulting in sweeter fruits, but with the relation Brix/acidity unfavorable. It is worth pointing out that in hotter climates, like in the Northeastern semiarid, grapefruits and 'Tahiti' acid lime present a thin peel and a very colorful pulp, besides a great productivity, when compared to fruits produced in others regions of the country. It is important to accentuate that in citrus cultivation under high temperatures, the period between flowering and maturation is reduced, what enables anticipation of the harvesting in relation to the others producing areas. Although having a potential for grapefruit, lemons and acid limes, there are small areas producing citrus in the São Francisco Valley, specifically with 'Tahiti' acid lime (**Figure 16**) [12]. In 2016, the results were 204 ha of planted area with the yield of 26.2 t/ha, in the following counties: Juazeiro, Casa Nova, Sobradinho and Curaçá [8]. In this region, due to its production characteristics, it is recommended rootstocks that determine reduced size to the canopy, drought tolerance and fruits of good quality, like rootstocks hybrids obtained by Embrapa Citrus Breeding Program in crosses with 'Trifoliolate' orange, 'Swingle' citrumelo and 'Troyer' and 'Argentina' citranges, among others. The citrandarins 'Indio', 'Riverside' and 'San Diego', obtained by USDA Citrus Breeding Program and recommended by Embrapa Mandioca e Fruticultura, are hybrids of 'Sunki' mandarin with trifoliolate orange, and have been highlighting in the Northeastern citrus scenario, because of their citrus foot-rot tolerance and production of good quality fruits. In researches with citrus fulfilled by Embrapa Mandioca e Fruticultura in partnership with Embrapa Semiárido, in Petrolina-PE and in Juazeiro-BA, it was verified that the grapefruit and the 'Tahiti' acid lime behave well. The Flame grapefruit (**Figure 17**) present thin peel and deep flesh color and





**Figure 16.** 'Tahiti' acid lime in Bahia—In Ascension in the northeastern region. Source: Nilton Sanches.

fair balance between Brix/acidity, what are considered outstanding characteristics [12]. Some sweet orange varieties have great potential under semiarid conditions, as the clones C-21, D-9, D-12 and D-25 of Pera, and Rubi, Westin, Salustiana, Natal CNPMF-112 and Valencia Tuxpan, besides 'Page' and 'Piemonte' mandarin hybrids [3]. Examining the different climatic situations, it is possible to point out as competitive advantages of the Northeast region: (1) multiplicity of climates and soils and area availability; (2) geographic privileged localization in relation to the main markets (Economic European Community and United States of America) in comparison to the others citrus fruit producers regions in the country; (3) non-occurrence of bacterial diseases, like the HLB (huanglongbing, ex-greening) and the citrus canker and others like leprosis (not in endemic form) and the black spot, which are causing serious losses to the Brazilian southwest citriculture, mainly in the States of São Paulo, Minas Gerais and Paraná.



**Figure 17.** 'Flame' grapefruit in the São Francisco Valley—An option for the regional citriculture. Source: Orlando Passos.

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