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AGRICULTURAL DIVERSIFICATION:

strategies for coping with climate risks in the Semiarid Region of Northeastern Brazil

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As a consequence, geneticists have described evolution simply as a change in gene frequencies in populations, totally ignoring the fact that evolution consists of the two simultaneous but separate phenomena of adaptation and diversification.

Ernst Mayr (German biologist)

As nature is aware, without diversity there is no evolution...

Isaias Raw (Brazilian physician)

Welcome, dear readers

The booklet **"AGRICULTURAL DIVERSIFICATION: strategies for coping with climate risks in the Semiarid Region of Northeastern Brazil'** is a tool developed to support the professionals that work with farming families to facilitate access to agricultural technical information that can guide farming production and social reproduction in rural areas.

This booklet is made up of 4 units:

1. Brazilian Semiarid

2. Climate risks

3. Coping with climate change

4. Rural activity diversification

a. Farming Diversification WITHIN the facility in the Brazilian Semiarid

i. Livestock diversification
ii. Temporary crop diversification
iii. Permanent crop diversification
iv. Horticulture diversification
v. Vegetal extraction diversification
vi. Forestry diversification
vii. Floriculture diversification
viii. Aquaculture diversification
ix. Forms of farming diversification

1. Intercropping
2. Crop succession
3. Crop rotation
4. Crop-livestock Integration (CLI)
5. Mixed farming systems
6. Agroforestry systems
7. Crop-Livestock-Forest Integration (CLFI)

b. Non-farming diversification WITHIN the facility

i. Agroindustry diversification

c. Diversification OUTSIDE the facility

The data sources were the 2006 and 2017 Agricultural Censuses.

There is a Glossary at the end of the booklet containing the meaning of several terms.

Recommendation: Your understanding can be increased by accessing the links and references provided in the booklet.

We hope this booklet will be very helpful!

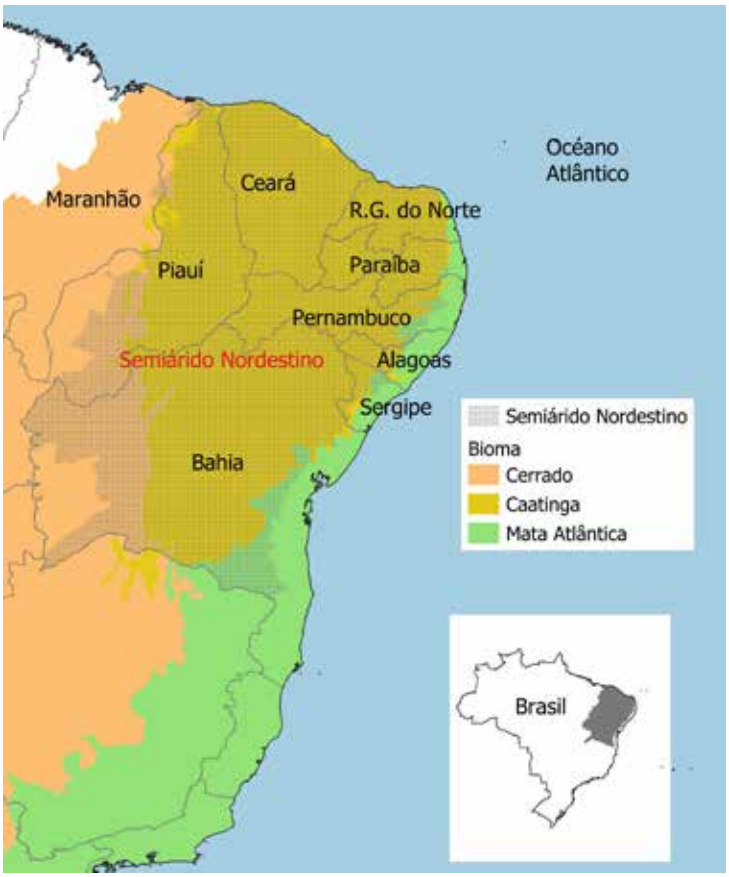
Diverse backyard - Rondas Pombos Settlement PE. Credits Fernando Falcão

1. BRAZILIAN SEMIARID

The semiarid region is composed of **1,262 cities** in the states of Maranhão, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe, Bahia, and Minas Gerais. The Brazilian Semiarid is the most populated semiarid area in the world (approximately 27 million Brazilians) and the rainiest (800 mm per year) compared to other similar regions in the world, where precipitation is between 80 and 250 mm per year. The area of the region covers approximately **11% of the Brazilian territory**. This region intersects with three biomes (see Map 1):

- **1. Caatinga:** the only exclusively Brazilian biome with rich biodiversity adapted to arid conditions, which presents vegetation with loss of leaves during the dry season.
- **2. Cerrado (savanna):** the second largest Brazilian biome with diverse vegetation, intense solar radiation, and dry winters.
- **3. Atlantic Forest:** presents biodiversity similar to the Amazon biome, in which the vegetation includes wet and dry areas.

Figure 1 - Map of the Northeastern semiarid biomes



Source: Prepared by the authors based on IBGE data.

2. CLIMATE RISKS

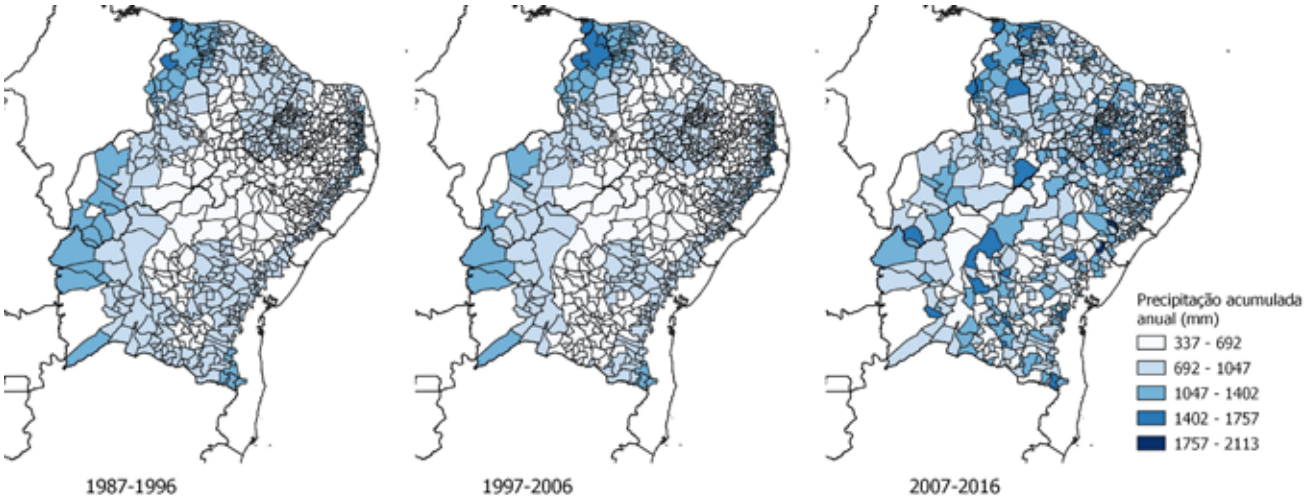
Climate change projections for South America indicate a temperature **increase between + 1.7 °C to + 6.7 °C for the year 2100**. In addition, climate variability is expected to increase, as well as the frequency and intensity of extreme events[1] (IPCC, 2014). A reduction in the total amount of rainfall is expected for tropical South America, as well as an increase in the number of consecutive dry days. According to the 2007 INPE (National Institute for Space Research) Climate Report, in a pessimistic scenario, temperatures would be 2 to 4°C warmer with a 15 to 20% decrease in rainfall in the semiarid region by the end of the 21st century. Conversely, in an optimistic scenario, temperatures would increase by 1 to 3°C and rainfall would decrease by 10 to 15%. Considering that, in the semiarid region, the current average annual precipitation is approximately 800 mm, consecutive days without rain (a "veranicos[2]" indicator) could increase by more than 30 days in 2071-2100 in the pessimistic scenario while today it is around 12 days. The increase in temperature could cause greater evaporation to lakes, dams, reservoirs, and plant evapotranspiration (MARENGO et al., 2011). In addition, it is expected that the northeastern part of the Northeast region will face increased precipitation rates during the summer (MACHADO FILHO et al., 2016).

On the other hand, studies show that climate change is likely to **impact crop productivity more negatively than positively** (IPCC, 2014). In the semiarid Northeast, there is a possibility that cassava production **will no longer be viable.** Furthermore, there is a risk that the semiarid vegetation will be replaced by arid vegetation (MACHADO FILHO et al., 2016). Several studies show adverse effects on Brazilian agriculture in general due to climate change. Climate change could reduce the productivity of corn, soybean, wheat, and rice by around 25% in future scenarios. Brazilian dryland farming could suffer economic losses of up to 14%. All these adverse effects can have severe consequences at the local level, especially in the country's poorest regions and for small farmers.

1 Extreme events are droughts, floods, tornadoes, windstorms, heat waves, frosts, cyclones, undertows, etc
2 Veranico is days between one rainfall and another, often very irregular in the Brazilian semiarid region, which occurs during the rainy season. To be considered veranico, an interval of at least four days without rain is needed (BRITO; CAVALCANTI; SILVA, 2014).

According to the climatic zoning of the Northeastern semiarid region in Map 2, it is observed that the patterns of the average annual cumulative precipitation vary slightly during the periods of 1987-1996 and 1997-2006. However, from 2007-2016, the rainfall zoning changed its pattern. In addition, the Northeast experienced an intense drought from 2012-2015, considered the most severe in recent decades. This severe drought affected more than 1100 cities in the Northeast (MARENGO; TORRES; ALVES, 2017). For instance, the severe drought of 2012-2013 in Ceará led to a 43% reduction in the harvested area. This led to an average loss of 75% in crops and caused livestock losses, with the cattle herd's death rate going from 0.33% in 2010 to 3.05% in 2013 (CEARÁ, 2013).

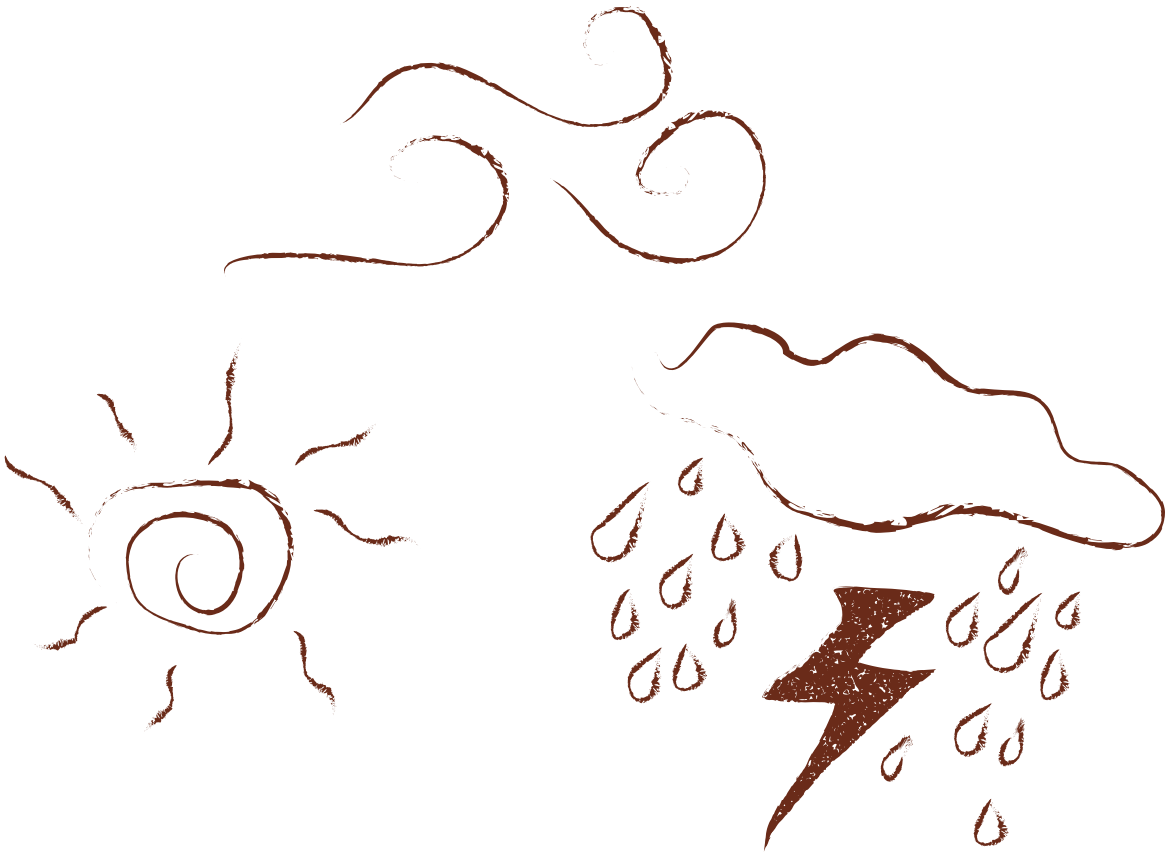
Figure 2 - Climate zoning map of the Northeastern Semiarid



Source: Prepared by the authors based on data from Global Meteorological Forcing Dataset for land surface modeling (SHEFFIELD; GOTETI; WOOD, 2006).

3. COPING WITH CLIMATE CHANGE

Different strategies for coping with climate risks depend on the type of soil, climate, cultural, institutional, and economic factors surrounding the farmers. These include the development of seeds that respond to climate variability, government programs, agricultural insurance, changes in farming practices, and agricultural credits. Therefore, proper planning for coping with climate-related uncertainties is required to analyze these existing options, taking into account their capacities and limitations. In this way, the vulnerability of farmers can be reduced and, at the same time, contribute to the sustainability of the system. In this context, diversification of rural activities has been acknowledged as an important coexistence practice to reduce risks and as a means of more resilient3 agrarian development[3].



3 Ability to adapt to bad weather, changes or misfortunes.

4. RURAL ACTIVITY DIVERSIFICATION

Rural diversification consists of developing several activities by some or several rural family members. In this way, there is the possibility of increasing the sources and forms of access to revenue, helping to reduce the variability of the farmer's income.

Diversification is divided according to the source of income, on- or off-farm. Both on- and off-farm income can be obtained from farming or non-farming activities. The settlement's farming activities are related to agricultural diversification, including cropping, livestock, forestry, and fishing. On the other hand, the non-farming activities within the establishment are those that, successively or simultaneously, complement the farming activities, such as tourism and food services and food and fiber processing activities (agroindustry). On the other hand, the incomes obtained from diversification outside the property are linked to the concept of pluriactivity (SCHNEIDER, 2007). Farming activities outside the establishment consist of steady and temporary jobs or renting their land or equipment. Non-farming activities include self-employment or salaried work in commerce and services, as well as income from retirement, pensions, or social programs (MCNAMARA; WEISS, 2005). The types of diversification depend on the broad agroecological and socioeconomic diversity that a region may have, as well as on its farming practices.

Productive diversification in the semi-arid region is an issue of great relevance for the region's sustainability. States such as Rio Grande do Norte and Sergipe rely more than 50% on activities within the settlement. In contrast, the others depend mainly on income from non-farming activities outside the rural settlement. In this context, it is worth mentioning the activities that can be significant income generators in rural establishments, such as rural tourism and product processing, with representation ranging between 4% and 9%, with great growth potential. On the other hand, guarantee systems that should provide support in production in semiarid conditions – Garantia Safra (Harvest Guarantee), Proagro Mais (Proagro Plus), Bolsas Verdes (Green Grants) – are not very representative in the farming income, ranging between 0.6% and 2.1% (See Figure 3).

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Figure 3 - Diagram of on- and off-farm diversification

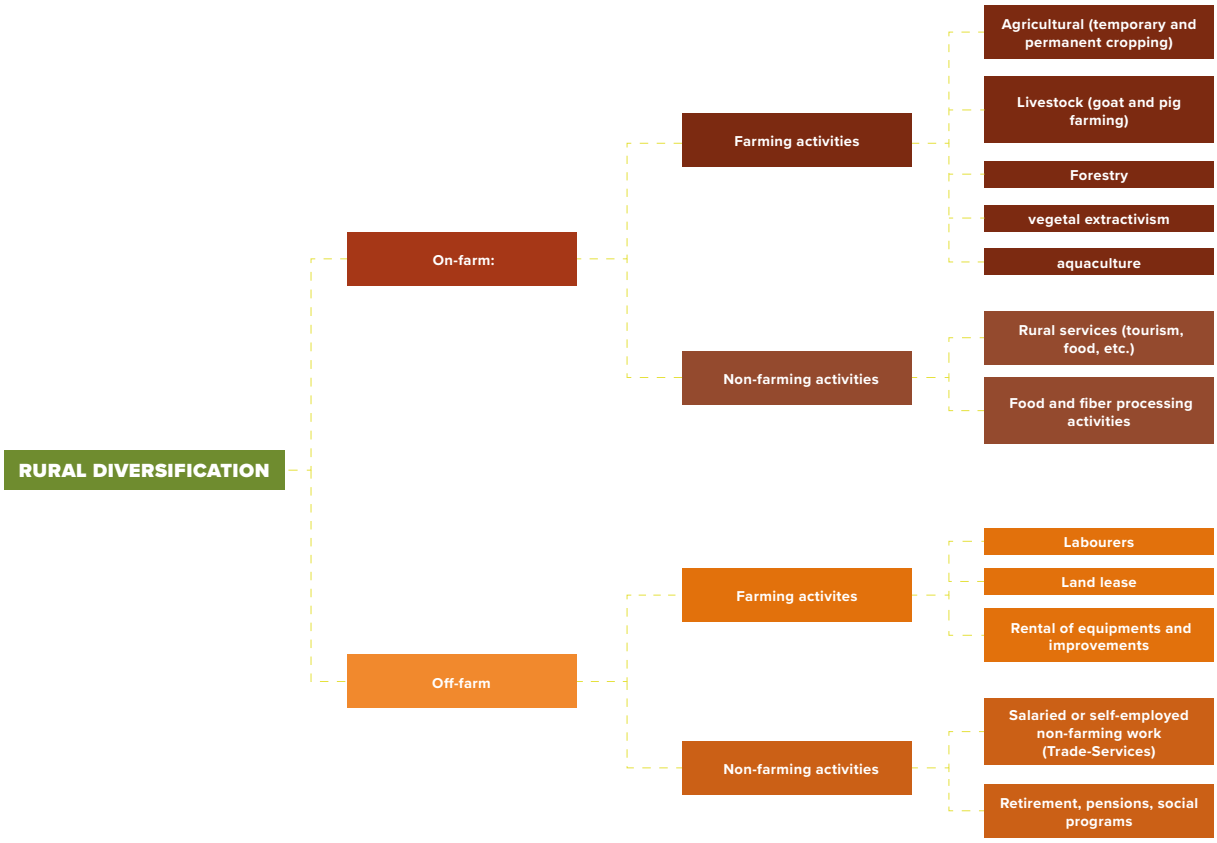
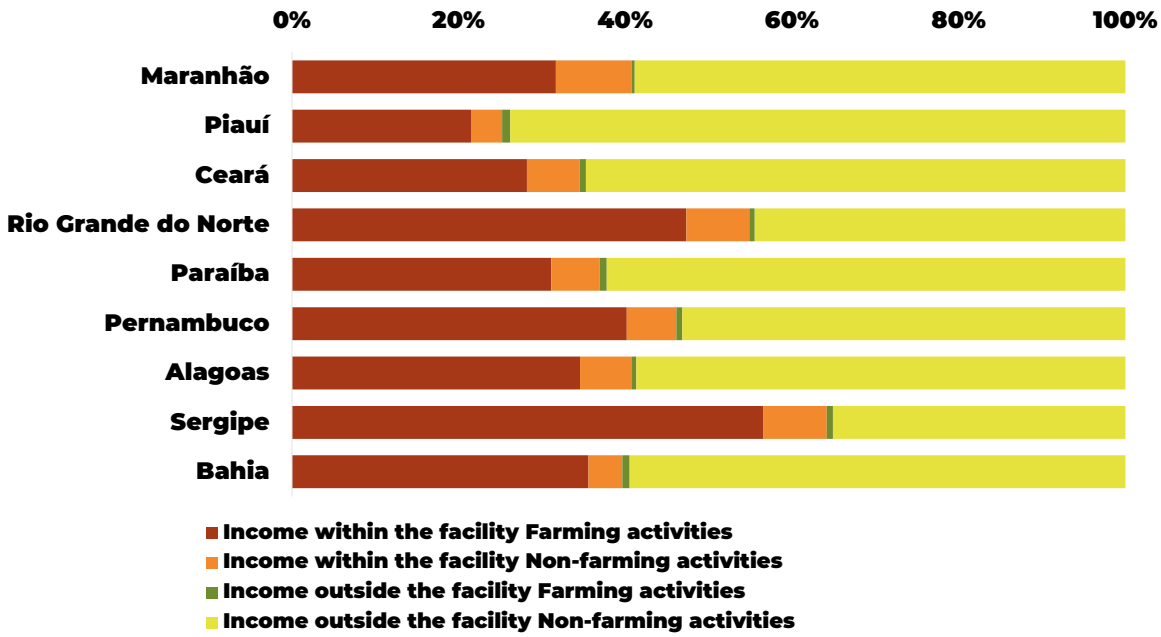


Figure 4 - Graph of income within and outside the facility of farming and non-farming in family farming agriculture in the semiarid region (2017)



Source: IBGE, Farming Census.

The following presents more details about the various types of diversification.

A. FARMING DIVERSIFICATION WITHIN THE FACILITY

Farming diversification refers to the various activities within the facility related to the mixed production of crops, livestock, forestry, vegetal extraction, and/or aquaculture. It considers the possibility of successive or simultaneous crops (simple, associated, and/or interspersed) in the same year and place. It enables income generation from different products, as well as provides a diversity of food products. Crop diversification through agroecological interactions can provide regulation services such as reduced soil erosion, increased moisture, reduced susceptibility to pests and diseases, and support services such as nutrient retention and soil fertility. At the same time, crop diversification can increase the efficiency of agricultural systems since there is a better use of standard inputs and scarce resources (water and fertile soils). On the other hand, farming diversification is associated with risk management, poverty reduction, adaptation to climate change, and improvement of farmers' food security.

The municipalities of the semi-arid region present a diversified agriculture, since most of them have high numbers in the Simpson index of farming diversification, as indicated in Figure 5. The Simpson index[4] is adapted from the ecological indices of species diversity, representing the concentration of species (MAGURRAN, 2004). This index considers how much each farming activity contributes to the total farming income of the municipality (SAMBUICHI et al., 2016). Numbers above 0.65 are considered very diverse, in which at least three products have the same participation in the municipality's local income. Values between 0.00 and 0.35 indicate that 80% or more of the Total Amount of agricultural and ranching income comes from only one product (SAMBUICHI et al., 2016). In other words, the income of most municipalities in the region is not centered on a few farming activities.

VISIT LINKS OF INTEREST:

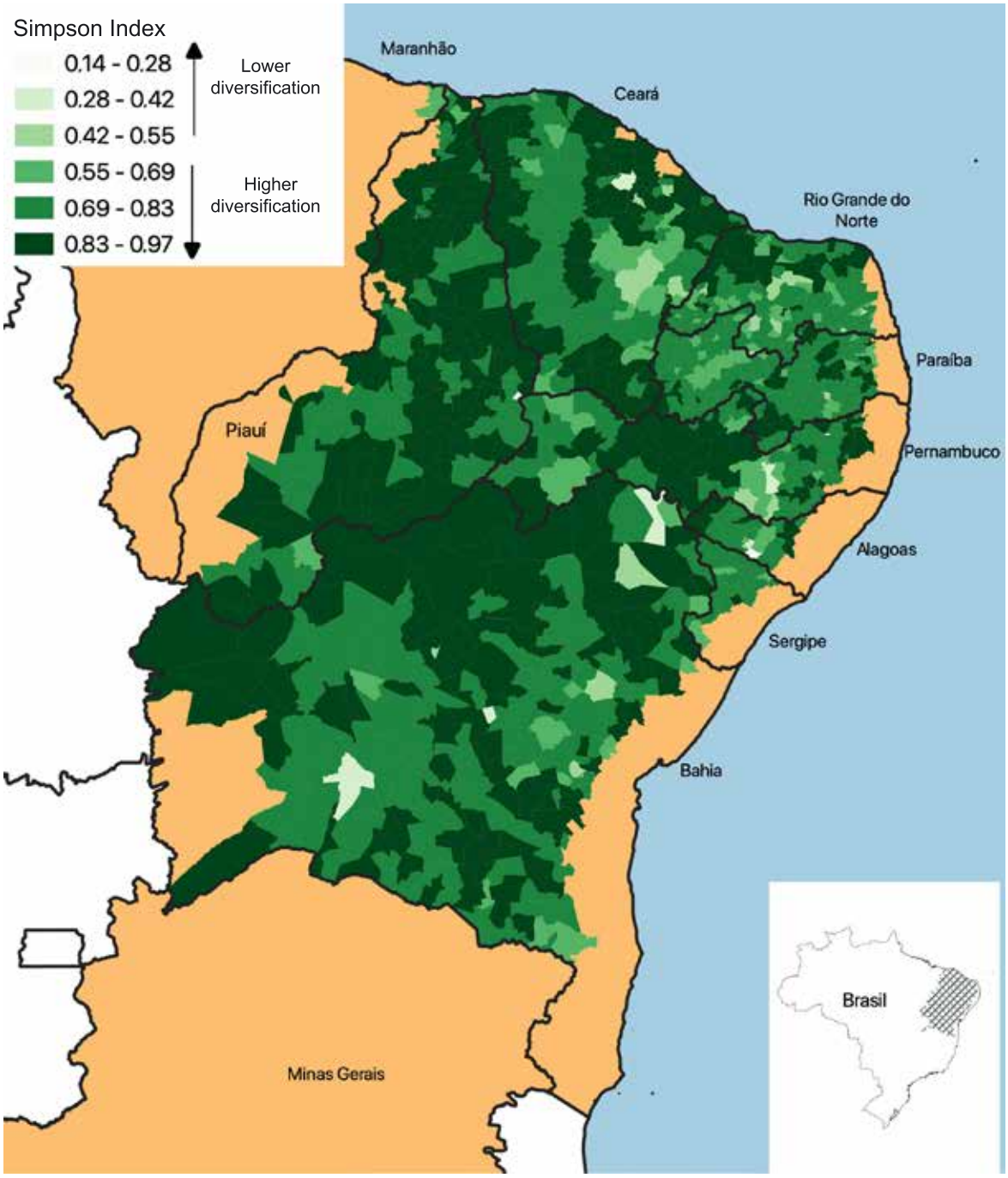
Diversification on agroecological farms:
https://www.gov.br/agricultura/pt-br/assuntos/sustentabilidade/organicos/fichas-agroecologicas/arquivos-praticas-conservacionistas/1-a-importancia-da-diversificacao-em-propriedade-agroecologicas.pdf

Biodiversity for Food and Nutrition:
http://www.b4fn.org/pt/curso-online/

Biodiversity reports for food and agriculture:
http://www.fao.org/state-of-biodiversity-for-food-agriculture/en

4 The formula to calculate the Simpson Index $:S_i = 1 - \sum_{k=1}^{n} a_k^2, 0 \leq S_i \leq 1$, where a_k is the proportion of the Production Amount of each product of temporary and permanent cropping, horticulture, forestry, vegetable extraction, floriculture, and aquiculture, as well as the Sales Amount of livestock in the Total Farming Amount of each municipality in the semi-arid region.

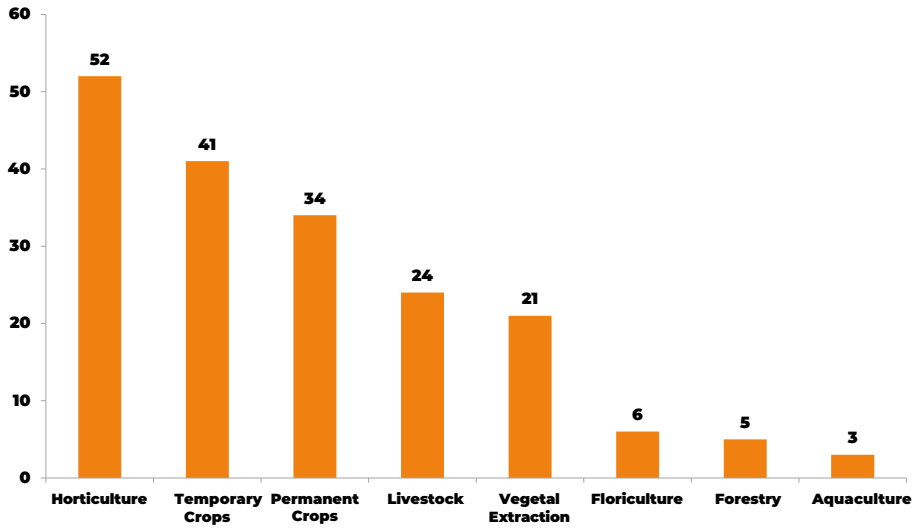
Figure 5: Farming diversification in family agriculture in the Northeastern semiarid in 2017



Source: Developed by authors based on data from IBGE (2017).
Note: The construction of the Simpson index considered the production amounts of temporary crops, permanent crops, horticulture, vegetal extraction, forestry, and the data on the sales value of livestock (does not include ducks, geese, teals, partridges and pheasants, turkeys, and ostriches), according to data available in IBGE's SIDRA.

In the Northeastern Semiarid, farming families produced a total of **186 farming products in 2017**, mainly in horticulture and temporary crops. There are few products in floriculture, forestry, and aquaculture (Figure 6).

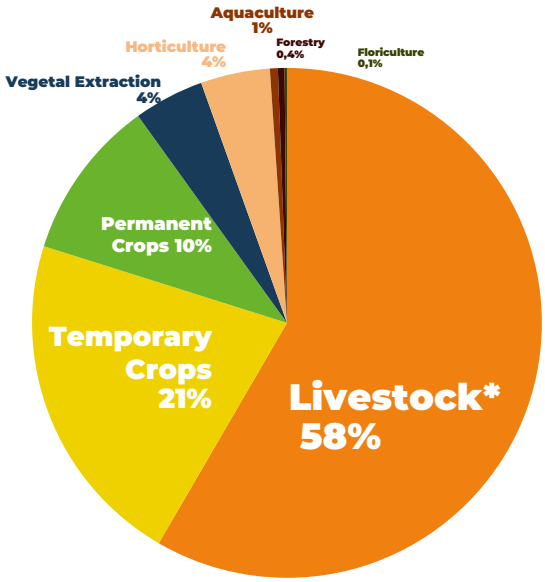
Figure 6 - Chart of the amount of family farming products from the Northeastern Semiarid region by Farming Sector in 2017



Source: IBGE, Farming Census

On the other hand, approximately 79% of the Total Value of Farming Products in the Semiarid in 2017 corresponded to the sectors of temporary crops and livestock (See Figure 7). Livestock had the largest share (58%) in the total value. Vegetal extraction and horticulture added a share of 8% to the total value. Aquaculture surpasses participation (approximately 1%) compared to forestry and floriculture. Next, the diversity of products per sector will be analyzed.

Figure 7 - Graph of the percentage of the Total Farming Products of Family Farming in the Northeastern Semiarid in 2017



Source: IBGE, Farming Census 2017

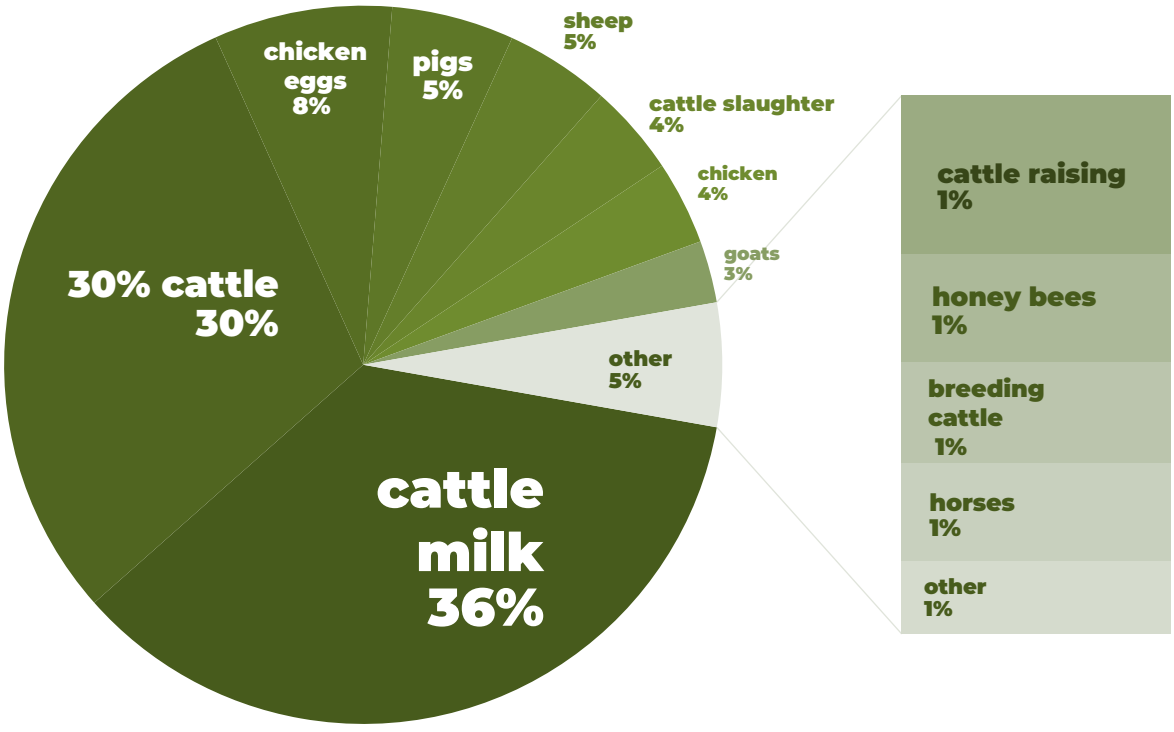
** Livestock does not include ducks, geese, teals, partridges and pheasants, turkeys, and ostriches.*

i. Livestock diversification in the Semiarid

1) Goat raising - Secundino Evaristo dos Santos, Aprisco Rústico, Paranazinho, Mirangaba - BA
2) Poultry raising - Quintal Vizinha Antoniel - Credits William França
3) Beekeeping - Piauí - Viva o Semiárido Project

As shown in Figure 8, more than 71% of the Total Livestock Value in 2017 is represented by cattle production, which includes the sale of milk, cattle, calves and male breeders, and the slaughter of cattle, as well as chicken and egg production, adds up to 12% of the total amount. The sale of goats represents 3% of the total value of livestock, and the sale of goat milk represents less than 1%. The production of honey has a participation of 1%, but it requires lower investments. Other products represent less than 1% of the total livestock value, such as goat milk, quail eggs, mules, quails, donkeys, beeswax, sheep milk, royal jam, bubaline heads, bubaline milk, rabbits, and sheep wool. For better detail by state, see Annex 1 at the end of the booklet.

Figure 8 - Graph of the percentage of the Total Cattle raising products of family farming in the Northeastern Semiarid (2017))



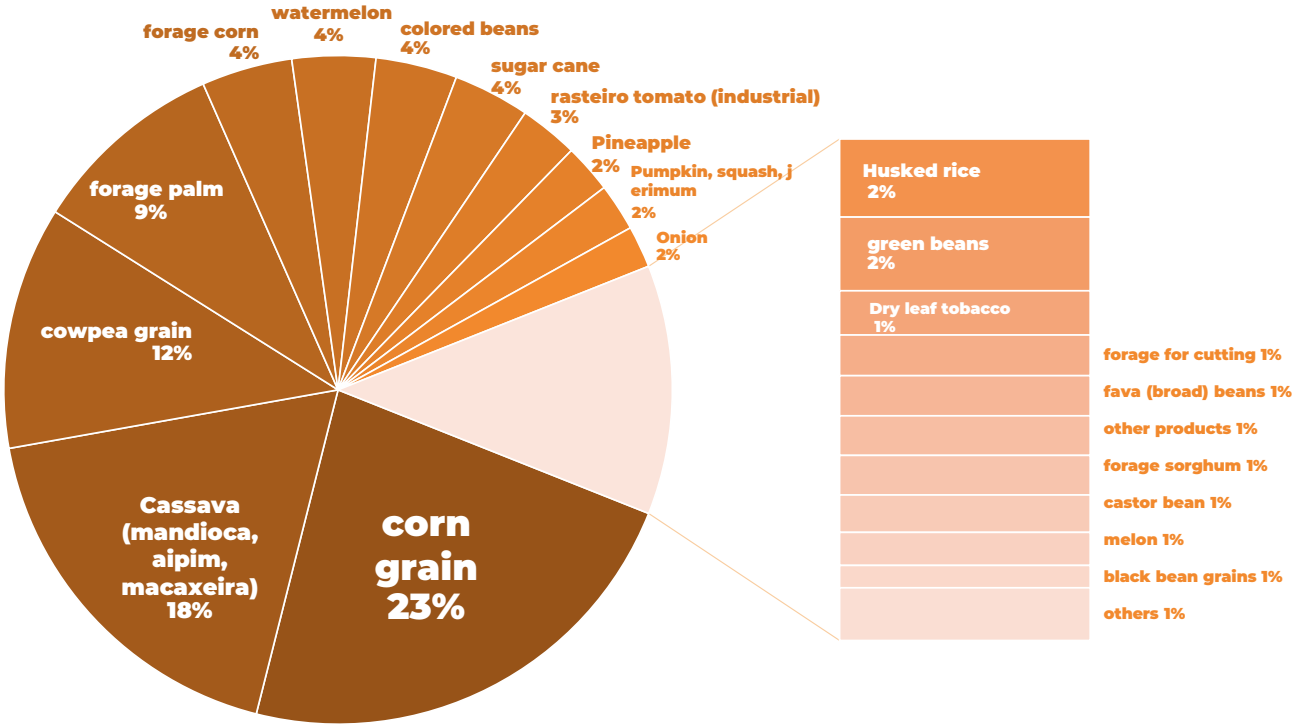
Source: IBGE, Farming Census

ii. Temporary crop diversification in the Northeastern Semiarid

1) Productive Backyard - Semear Project - Credits William França
2) Forage Palm – Antoniel Backyard - Credits William França
3) Cassava - Antoniel Backyard - Credits William França

The Temporary Crop products ranked in second place (21%) in the total of all Family Farming - FF products in the Northeastern Semiarid region. In Figure 9 it can be seen that the Temporary Crop products are more diverse. However, more than 53% is centered on three crops: corn grain (23%), cassava (18%) and cowpea grain (12%). Then comes the forage palm[5], with 9% of the total amount, followed by forage corn, watermelon, colored beans and sugar cane, with a share of 4% each. In the last parcel, there are Others (1%), which include all products with less than 1% share: garlic, grain sorghum, forage cane, peanuts, herbaceous cotton, soybean grains, English potatoes, beans (produced for planting), seeds and other forms of propagation of other products (produced for planting), sesame (seed), forage seeds (produced for planting), corn seeds (produced for planting), broomcorn sorghum, ramie (fiber), rice seeds (produced for planting), cotton seeds (produced for planting), sunflower (seed), pea seeds, sugar cane stalks (produced for planting). For a detailed view by state, see Annex 2.

Figure 9 - Graph of the percentage of the Total TEMPORARY FARMING products of family farming in the Northeastern Semiarid (2017)



Source: IBGE, Farming Census.

5 *Although the forage palm is considered a temporary crop in the Farming Census, it requires annual cutting and there is no replanting.*

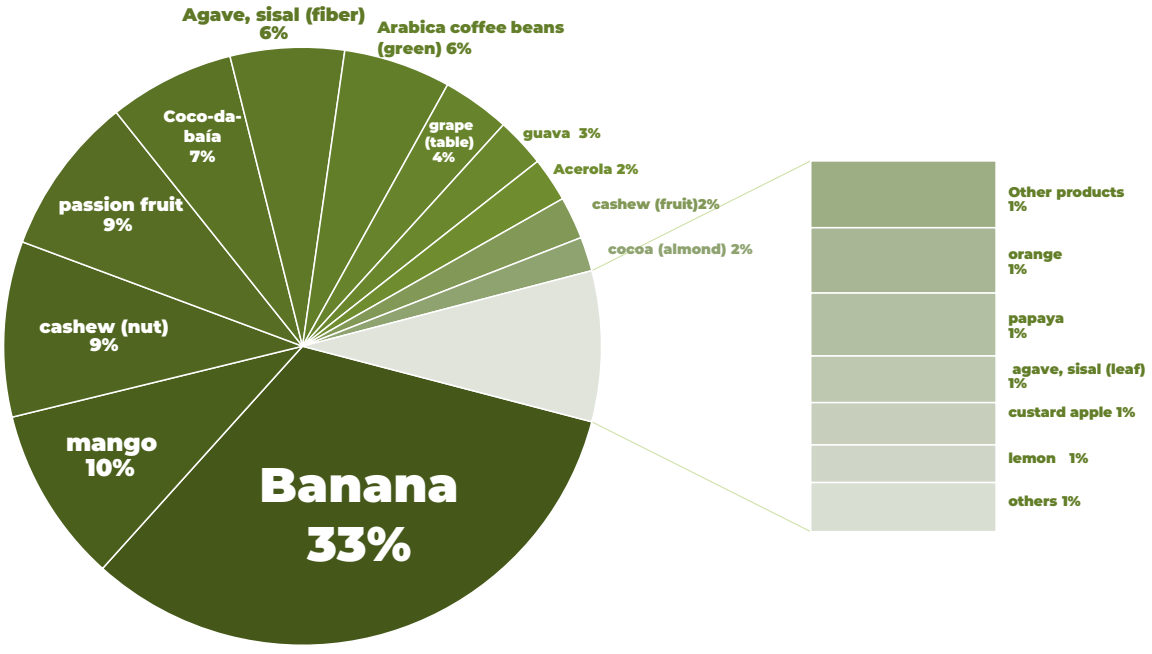
iii. Permanent crop diversification in the Northeastern Semiarid

1) Mango - Perpetua Backyard - Credits William França

2) Banana - Babaçu Backyard - Credits William França

Permanent crops include the plantations of long-duration crops, which, after harvest, do not need to be planted again, producing for several successive years (IBGE, 2002). Figure 10 shows the participation of the permanent crops in the Northeastern Semiarid region. It can be observed that banana was the product that had the greatest participation (33%). Then follows the cashew nut and fruit culture, which add up to 11%. In the sequence, the mango, with 10%, and passion fruit, with 9%. The products of permanent crops were more diversified, however, bananas and cashew were the most significant products in the semiarid. Thus, there are some other products from this sector that can be further identified as income sources. The term Other classifies the permanent crops presenting values lower than 1%: tangerines, avocado, urucum (seed), soursop, jackfruit, black pepper, pineapple, jabuticaba, canephora coffee (robusta, conilon) in grain (green), pomegranate, guaraná, açaí (fruit), grapes (for wine or juice), cupuaçu, dendê (coconut) and rubber (coagulated latex). The details of production by state are shown in Annex 3.

Figure 10 - Graph of the percentage of the Total PERMANENT CROP products of family farming in the Northeastern Semiarid (2017)

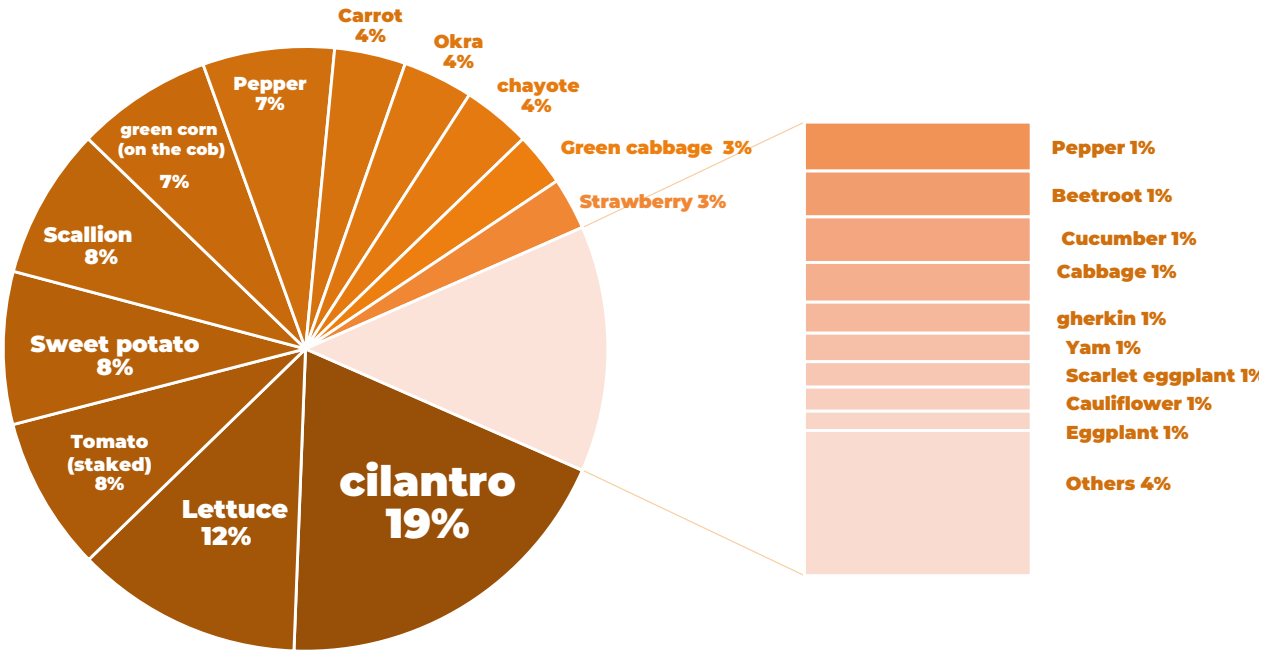


Source: IBGE, Farming Census.

iv. Diversified Horticulture in the Northeastern Semiarid

Horticulture involves the exploitation of vegetals, such as leaf crops, roots, bulbs, tubers, various fruits, and edible parts of plants. Figure 11 presents the share of horticultural products in the FF of the Northeastern Semiarid region in 2017. In this region, horticulture contributed approximately 4% of Family Farming Products in the Northeastern Semiarid in 2017 (Figure 11). Five products (cilantro, lettuce, tomatoes (staked), sweet potatoes, and chives) accounted for the majority (approx. 56%) of the total amount in horticulture. However, cilantro was the main product (19%) in this sector. The category Other includes the horticulture products less than 1%: These are arugula, broccoli, zucchini, parsley, cará, chard, pods (string beans), other products (not specified), mint, spinach, seedlings and other forms of propagations (produced for planting), baroa potato (mandioquinha), seeds (produced for planting), leek, fennel, basil, cress, radish, rosemary, celery, ginger, mustard (seed), turnip, chicory, radicchio, elm, bertalha, boldo, loofah (vegetable sponge), chamomile, peas (pod). Annex 4 shows the horticultural products by state.

Figure 11. Percentage of the Total HORTICULTURE products of family farming in the Northeastern Semiarid (2017)



Source: IBGE, Farming Census.

Box 1

Agroecological Booklet and the Women of the Semiarid

Agroecological Booklet. Antônia de Sousa Castro. Barreiros II Community, City of Tauá, CE. Paulo Freire Project Collection

In Brazil, about two-thirds of rural women work unpaid or for their consumption. However, this work contributes to families' nutrition and food security, especially with the diversification of poultry and small animal farming and horticulture/floriculture (MELO; SABATTO, 2009). In this sense, the Agroecological Booklet becomes a tool that allows the visibility of women's work in rural areas. It records the products women generate in family and farming agriculture daily, destined for self-consumption, exchange, donation, and sale. The results of the registry of 879 women in seven states of the Northeast -Alagoas, Bahia, Ceará, Paraíba, Pernambuco, Piauí, and Sergipe - show that they produce a total variety of 1,228 different products, including animal, plant, and mixed (foods prepared with a mixture of animal and plant products) crafts, seedlings and seeds, medicinal plants, services, and others.

The data were extracted from the economic analyses of the data recorded by the women farmers involved in the projects supported by the International Semear Program (PSI)/IFAD in the book: "Agroecological booklets and the women of the semiarid region hand in hand strengthening agroecology: results of the use of the booklets in the projects supported by IFAD in Brazil from August 2019 to February 2020" (IFAD, 2020).

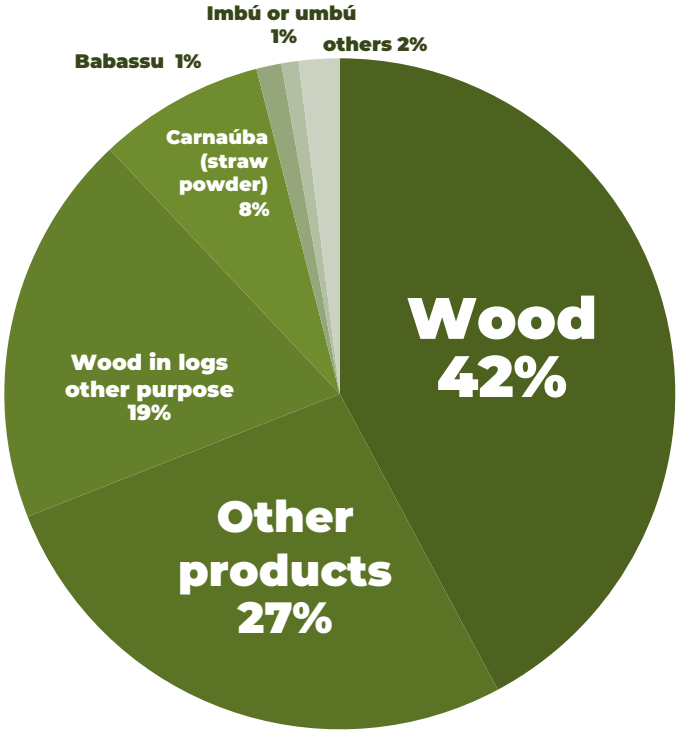
"The use and follow-up of the booklets in our community is helping with our work. Today I have in my backyard the cultivation of vegetables, medicinal plants, and fruit trees like acerola, umbu, seriguela, cashew, and we have discovered how to cultivate others. We can make our own delicious pulps, juices and sweets. Besides, when we don't produce, we buy from a friend, and it is one more little source of income for all of us...". (Francisca de Deus, president of the São José de Cocos/Ipiranga - Piauí association. Viva o Semiárido Project (IFAD, 2020)

v. Vegetal extraction diversification in the Northeastern Semiarid

SAF with carnaúba - Credits William França

Vegetal extractivism is linked to the exploitation of native forest resources. In 2017, vegetal extraction accounted for, on average, approximately 4% of the total value of the Agricultural Products of the Northeastern Semiarid Family Farming. Figure 12 presents the participation of the products of Vegetal Extraction. Firewood is the main product (42%) in this sector, followed by other products (27%) which were not specified in the last Agricultural Census. Wood logs for other purposes (19%) occupy third place. In fourth place (8%) is the Carnauba straw powder, which is collected from the leaves of the palm tree, native to the Northeast and known as the "queen of waxes", to be used as an ingredient in formulas for cosmetic, pharmaceutical, or food industries. The category Others includes the products of vegetal extraction with values below 1%, which totaled 15 products: pequi, licuri (coconut), wood for papermaking, buriti (coconut), carnauba (wax), cajarana, babassu (almond), mangaba (fruit), licuri (wax), buriti (straw), murici, bacuri, macaúba (fruit), araticum (fruit) and cagaita (fruit). For more details by state, see Annex 5.

Figure 12 - Graph of the percentage of the Total VEGETABLE EXTRACTION products of family farming in the Northeastern Semiarid region (2017)



Source: IBGE, Farming Census .

Although umbu presents a 1% share, the Family Farming Cooperative of Canudos, Uauá, and Curaçá (COOPERCUC) in the hinterlands of Bahia has managed its national and international marketing (France, Austria, Italy). As well as other products from the extraction of native plants from the Caatinga, through sweets, jellies, pulps, jams, syrups for ice cream, and vinegar, among others, thus improving the income (approx. 30% in 2009) of the cooperative members. COOPERCUC today brings together 16 associations and 16 mini fruit processing units, involving about 300 families (IFAD, 2019).

Figure 13 - COOPERCUC products

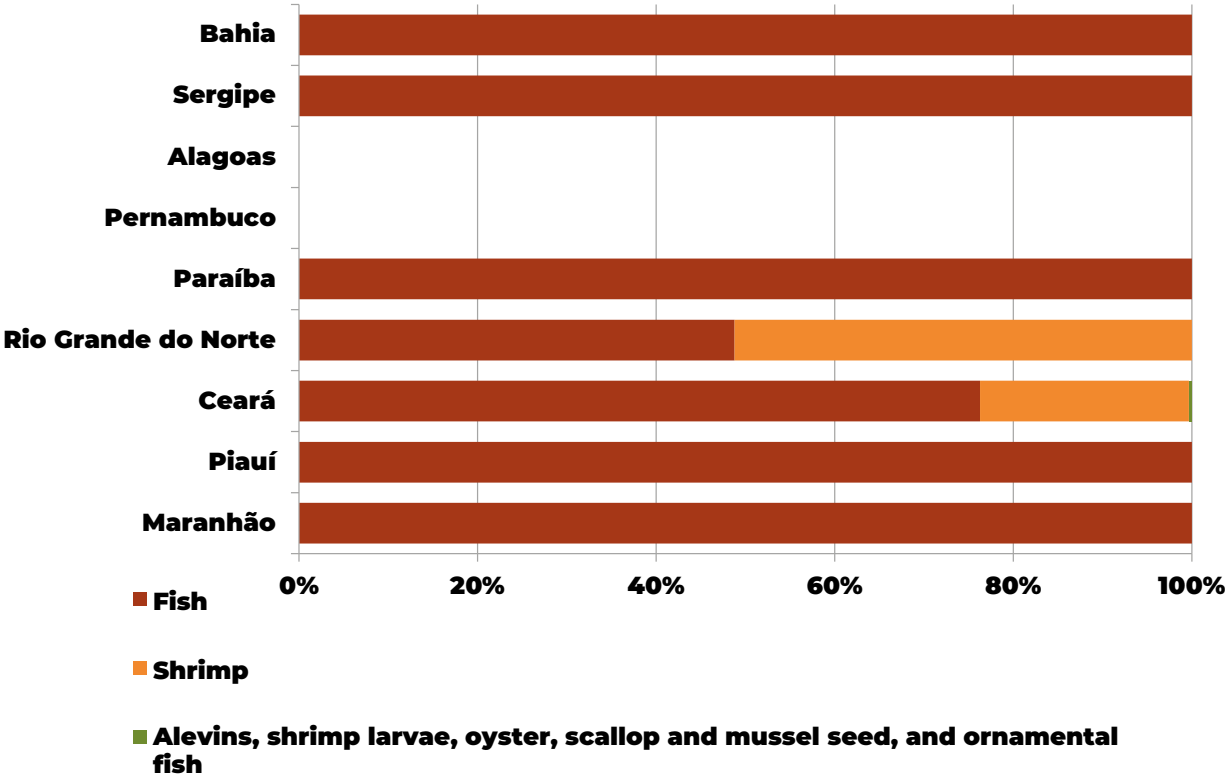
Source: IFAD - International Development Fund

vi. Aquaculture Diversification in the Northeastern Semiarid

Photo 1 and 2 - Dom Távora Project-Sergipe. Photo by Ednilson Barbosa - SEAGRE - SE

A aquicultura na AF do Semiárido Nordestino representou 1% do valor total, Aquaculture in the FF of the Northeastern Semiarid represented 1% of the total value, surpassing forestry and floriculture. Figure 14 shows each state's contribution to FF's aquaculture production. Almost all the Northeastern states contribute to the production in this sector, except Alagoas and Pernambuco. The main product is fish, so it is the only product of this activity in Bahia, Sergipe, Paraíba, Piauí, and Maranhão. Farming Census **does not specify the different types of fish produced. In the State of Rio Grande do Norte, a little more than half of the aquaculture is for shrimp production, and the rest is for fish.** In Ceará, shrimp production represents around 23% and less than 1% in producing alevins, shrimp larvae, or others. Thus, the most significant participation in this state is fish production, with 76% of the total value in aquaculture.

Figure 14 - Graph of the percentage of the Total AQUICULTURE products of family farming by states in the Northeastern Semiarid (2017)

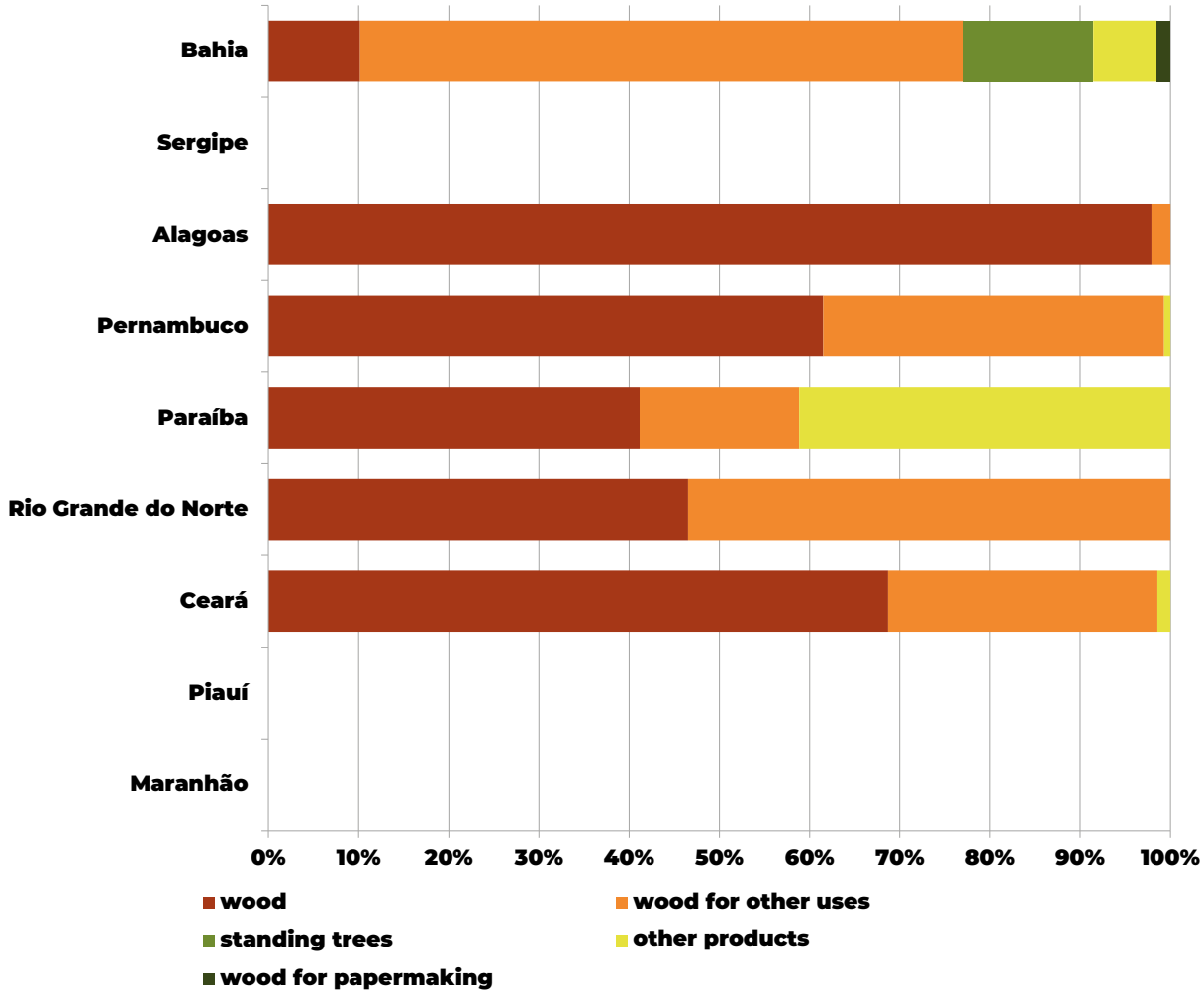


Source: IBGE, Farming Census

vii. Forestry Diversification in the Northeastern Semiarid

Forestry is related to planted forests. In the semiarid region, forestry represented, on average, approximately 0.4% of total farming income in 2017. Figure 15 presents the share of FF forestry products in the Northeastern Semiarid region. The states of Maranhão, Piauí, and Sergipe did not present any forestry production. Wood from planted forests is the main product in Ceará (69%), Pernambuco (62%), and Alagoas (98%). In Bahia, the forestry products were more diverse, with roundwood for other uses representing approximately 67% of production, followed by standing trees (14%), wood for papermaking (1.5%), and other forestry products (7%).

Figure 15 - Chart of the percentage of the Total SILVICULTURE products of family farming by states in the Northeastern Semiarid (2017)

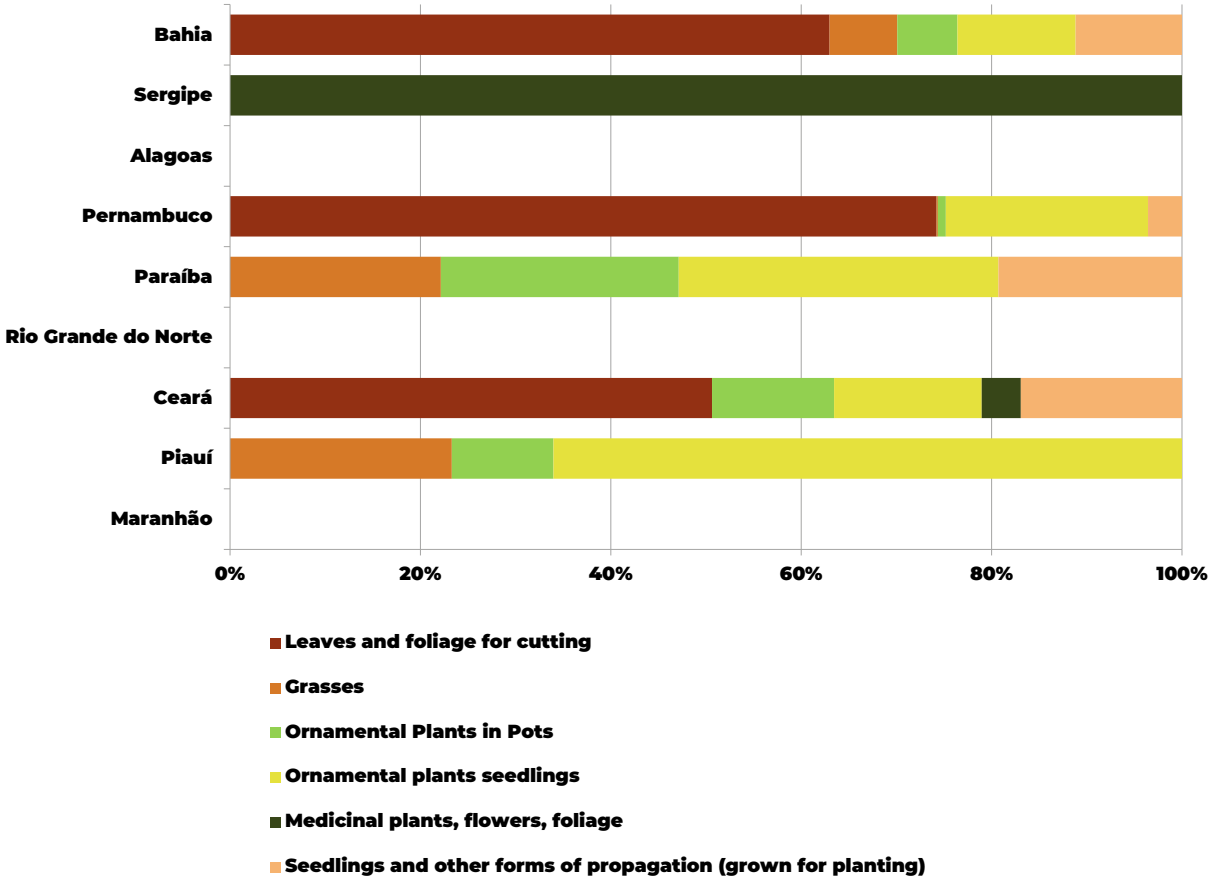


Source: IBGE, Farming Census .

viii. Floriculture Diversification in the Northeastern Semiarid

The production of flowers had an insignificant representation, 0.1%, in the total agricultural products from FF. However, as highlighted in the Vila Real Flowers Project, they are potential products (Box 3). Figure 16 shows the share of floriculture products in FF, divided by state. Three states with no production in this sector stand out: Alagoas, Rio Grande do Norte, and Maranhão. The state of Sergipe develops a single product with medicinal plants, flowers, and foliage. In Bahia, Pernambuco, and Ceará, the main products are flowers and foliage for cutting accounting for 63%, 74%, and 51%, respectively. In Piauí, the outstanding products are ornamental plant seedlings, with 66% of the total value.

Figure 16 - Graph of the percentage of the Total FLORICULTURE products of family farming by states in the Northeastern Semiarid (2017)



Source: IBGE, Farming Census

ix. Forms of farming diversification

Among the main forms of agricultural diversification are:

a) intercropping

b) succession cropping

c) crop rotation

d) crop-livestock integration

e) mixed farming systems

f) agroforestry systems

g) crop-livestock-forest integration

Family farmer and her daughter - Salgado Community - Andorinha_Foto_ManuelaCavadas

Farming Diversification: INTERCROPPING

Intercropping, or crop mixture, refers to the simultaneous cultivation of two or more plant species in the same area, at least for part of the same time. The arrangement of crops in the same space can be in alternate rows, strips, or mosaics, with one serving as a border or cover for the other, with or without a defined pattern. Intercropping involves using soil nutrients, water, light, and pest prevention because there is agroecological interaction among the intercropped species. For example, the intercropping of corn-bean-jerimum (pumpkin) brings positive interactions: the bean, as a legume, nitrifies the soil (main element in fertilization), while the corn helps as a support mechanism for the growth of beans and shade for the jerimum; and, in turn, the jerimum benefits the intercrop by controlling spontaneous vegetation and unwanted insects.

The most common intercropping is the one of cereal (corn, sorghum) with legume (beans, fava beans), but there are also the simultaneous cultivation of tubers/roots (potato, cassava, macaxeira) and legumes, and between fruit trees (cajá, jackfruit or papaya with coffee).

Research results indicate that two-crop intercropping can produce, on average, 38% more gross energy, 33% more gross income, and use 23% less land (MARTIN-GUAY et al., 2018).

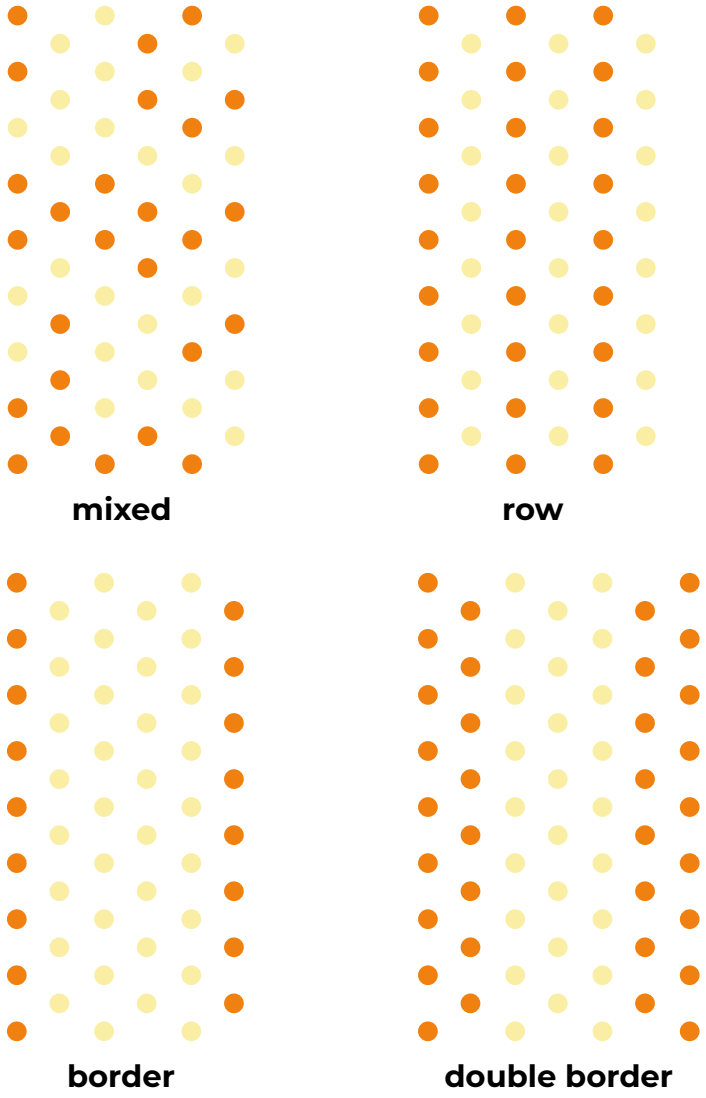
However, the efficiency of intercropping depends on the density and type of each plant species that make up the system to complement each other. An example is the combination of carrots at 40% of the density of the Recommended Single Cropping Population (PRCS) with arugula at 100% of the PRCS, which contributed higher values in economic and agricultural indicators in the Northeast region of Brazil (BATISTA et al., 2016).

Corn-beans intercropping - Credits William

Intercropping should attempt to reduce competition for light, water, and nutrients. Thus, it is important to consider that they present:

- **Different life cycles. E.g.:** the cycle of the carrot is 90 to 120 days, and that of the lettuce is about 45 days.
- **Different types of roots.** E.g. deep roots (legumes) with shallow roots (cereal).
- **Different requirements** for sun or shade.
- **Hedges can:**
  - **harbor natural enemies of pests.** E.g. fennel (Pimpinella anisum L.) or cilantro (Coriandrum sativum L.) attract ladybugs that control aphids.
  - **repel harmful insects.** E.g. garlic and sunflower repel harmful insects in general.
  - **help maintain soil moisture.** E.g.: banana

Figure 17 - Possible intercropping patterns



Source: https://www.hortabiologica.com/2012/12/consociacao-culturas/

VISIT LINKS OF INTEREST:

Plant intercropping

Companion Plants

Enemy Plants

Corn-beans-jerimum intercropping

Kale-cilantro intercropping

Pineapple intercropping

Papaya-coffee intercropping

Coffee-Banana intercropping

Contour lines

Green fertilization to control spontaneous plants

Intercropping of guandu (pigeon pea) with corn or sorghum for silage production

Farming diversification: SUCCESSION CROPPING

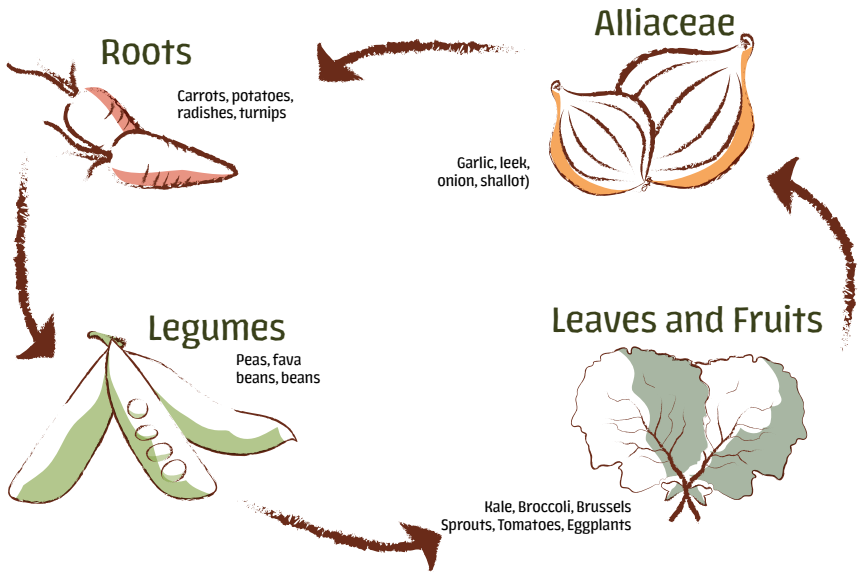
The succession cropping system consists of a sequence of crops in the area within one year. The crop sequence differs from intercropping in that different species can be sown at different times after the harvest of one of them in the same area. This is because successions of the same crops in the same area can increase the occurrence of pests and diseases and, consequently, decrease productivity.

A mixture of succession and intercropping can bring better results than monocultures. Several experiments indicate that repeating cereal succession crops reduces their productivity, while well-balanced intercrop successions that include legumes have resulted in the highest cereal crop productivity. As an example, the study by Barbosa et al. (2013) in a semiarid region of Ceará shows that the use of banana intercropping with tropical cudzu (Pueraria phaseoloides) in succession to crotalaria (Crotolaria juncea) and calopogonium (Calopogonium muconoides L) in succession to pork bean (Canavalia ensiformes) had a positive influence on the growth and production of banana, and on the supply of nitrogen, even partially replacing mineral fertilizer.

Farming diversification: CROP ROTATION

Crop rotation involves alternating crops in the same area over several agricultural years. This rotation takes place annually or over longer periods and always repeats a pre-established order, distinguishing it from crop succession. For example, for two or three years, one should not cultivate (rest period) in the same area with tubers but rotate with other species, such as legumes or cereals. The rotation is preferably alternated with crops with different root systems (grasses and legumes) (See Figure 18). The agricultural benefits of crop rotation range from breaking disease cycles to reducing soil erosion and nitrogen losses.

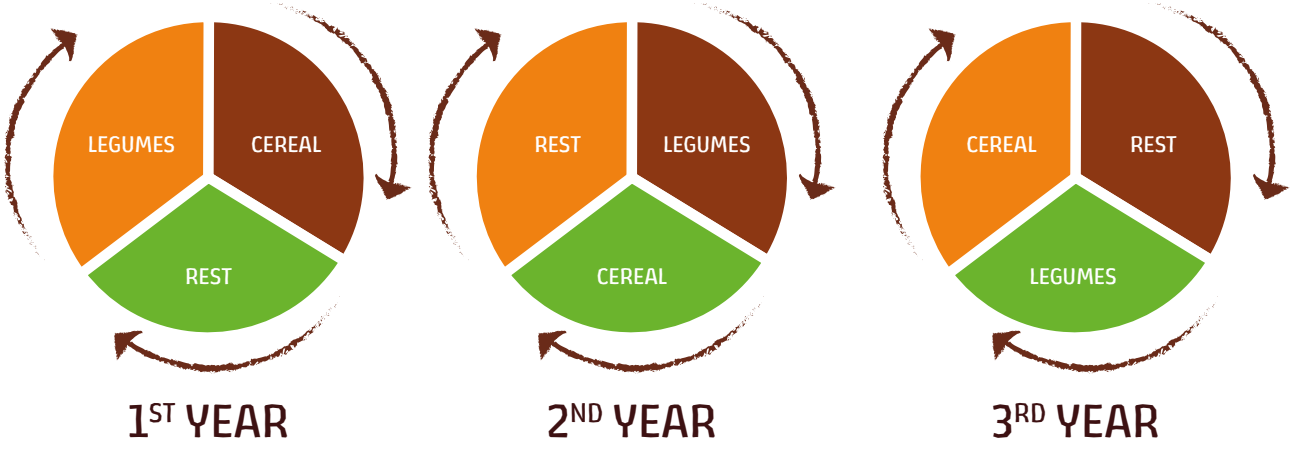
Figure 18 - Horticultural crop rotation



Source: Semear & Plantar

In crop rotation, alternation occurs over annual or longer periods, waiting for 3 or more crops of different types or resting crops to break pathogen cycles (Figure 19).

Figure 19 - Possible crop rotation patterns

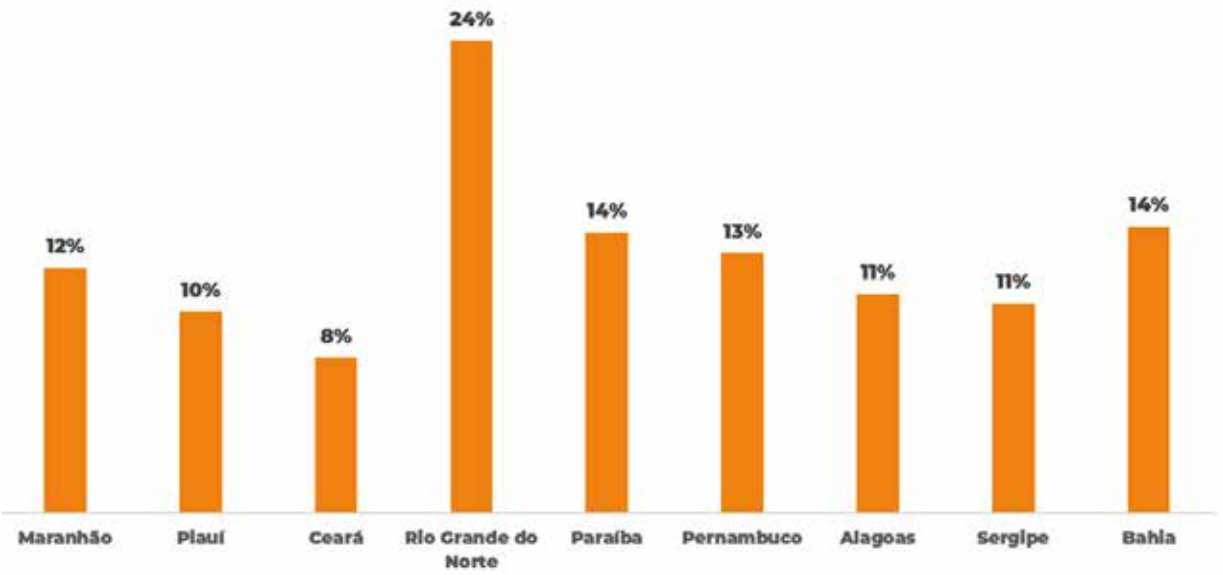


	AREA 1	AREA 2	AREA 3	AREA 4
YEAR 1	LEAVES	FRUITS	ROOTS	LEGUMES
YEAR 2	FRUITS	ROOTS	LEGUMES	LEAVES
YEAR 3	ROOTS	LEGUMES	LEAVES	FRUITS
YEAR 4	LEGUMES	LEAVES	FRUITS	ROOTS

Source: GREENBERG, Joshua, 2020.

In the northeastern semiarid region, crop rotation is highlighted in Rio Grande do Norte, with 24% of the FF establishments (Figure 20). Then follow Bahia and Paraíba, with 14%. The state of Ceará presents the lowest percentage (8%) of FF establishments that carried out crop rotation.

Figure 20 - Graph of percentage of family farming establishments that use CROP ROTATION in the states of the northeastern semiarid (2017)



Source: IBGE, Farming Census

VISIT LINKS OF INTEREST:

Crop rotation
https://www.gov.br/agricultura/pt-br/assuntos/sustentabilidade/organicos/fichas-agroecologicas/arquivos-praticas-conservacionistas/5-rotacao-de-culturas.pdf

https://ainfo.cnptia.embrapa.br/digital/bitstream/CNPSO-2009-09/27612/1/circtec45.pdf

Crop rotation in horticulture
https://www.gov.br/agricultura/pt-br/assuntos/sustentabilidade/organicos/fichas-agroecologicas/arquivos-producao-vegetal/1-rotacao-de-culturas-em-hortalicas.pdf

Corn-based crop rotation
https://www.gov.br/agricultura/pt-br/assuntos/sustentabilidade/organicos/fichas-agroecologicas/arquivos-producao-vegetal/2-rotacao-de-culturas-com-base-na-cultura-do-milho.pdf

Direct planting crop rotation
https://www.embrapa.br/busca-de-publicacoes/-/publicacao/820422/rotacao-de-culturas-em-plantio-direto

Farming Diversification: AGROFORESTRY

The agroforestry system (AFS) combines planted forests or native forests with temporary crops, fruit trees, bushes, and forage plants in the same area. These systems allow structures similar to native vegetation to be maintained and thus aid in the recovery of degraded areas. The SAF allows planting products for self-consumption (wood, firewood, fruits, forage, tubers/roots, and medicinals) and products destined for the market (beekeeping, coconut, coffee, cocoa). However, great care is needed when choosing species, as some combinations of permanent crops or forestry with annual cultivation could be more suitable. However, associating native or exotic fruit trees with early cocoa or coffee has been successful (FAO, 2015).

According to Ambrosio (2013), there are several agroforestry systems in the Northeast, among which are the following: Improved Capoeira; Taungya; Alley cropping; Tree cultivation in a multi-stratified pattern; Domestic orchards or productive backyards; Hedgerows and windbreaks; Trees in native or introduced pastures; Forested areas associated with grazing; Protein bank; Ecological swiddens; and Productive backyards with animals.

In IFAD projects in Brazil, we highlight the implementation of 31 AFS in the semiarid region of Paraíba through PROCASE, 20 systems in Bahia (Pro-Semiarid), and 3 in Ceará (Paulo Freire Project). It is worth noting that until 2020, IFAD projects in the Northeast implemented at least 2971 forage fields in the region.

Among the cultural practices, one of the most important for the Northeast is to mulch the soil in order to to reduce water evaporation, improve thermal control, biological life, and protection against erosion. Another important technique is pruning in the management of the AFS to rejuvenate aging trees and open spaces for sunlight penetration. This enables the planting of short-cycle crops.

For the cultivation of AFS in the semiarid region, it is important to consider the rainfall cycle, crops adapted to the region, adequate spacing, vegetation cover, production capacity, and market.

VISIT LINKS OF INTEREST:

Agroforestry systems:
https://www.gov.br/agricultura/pt-br/assuntos/sustentabilidade/organicos/fichas-agroecologicas/arquivos-producao-vegetal/13-sistema-agroflorestais.pdf
https://www.embrapa.br/codigo-florestal/sistemas-agroflorestais-safs

Agroforestry for family agriculture:
https://ainfo.cnptia.embrapa.br/digital/bitstream/CENARGEN/23823/1/ct016.pdf

Agroforestry systems for small properties in the Brazilian semiarid region:
https://www.embrapa.br/e-campo/sistemas-agroflorestais-para-pequenas-propriedades-do-semiarido-brasileiro

Sowing knowledge, inspiring solutions: Good Practices in Coping with the Semiarid:
http://portalsemear.org.br/publicacoes/semeando-saberes-inspirando-solucoes-boas-praticas-na-convivencia-com-o-semiarido/

AFS - Credits William França

"In the beginning, when the trees have not yet grown enough to shade the area, the farmer can plant whatever he wants, but mainly vegetables, beans, corn, and forage, like Iranildo's family did (FAMÍLIA GARCIA - Sítio Passagem do Carro in Penedo, São José do Sabuji - Paraíba). Thus, in a short time, you will have production. The soil of the crops should always be covered by a thick layer of organic matter, as happens in a forest" (SENTO SÉ, 2017).

Farming diversification: CROP-LIVESTOCK INTEGRATION (CLI)

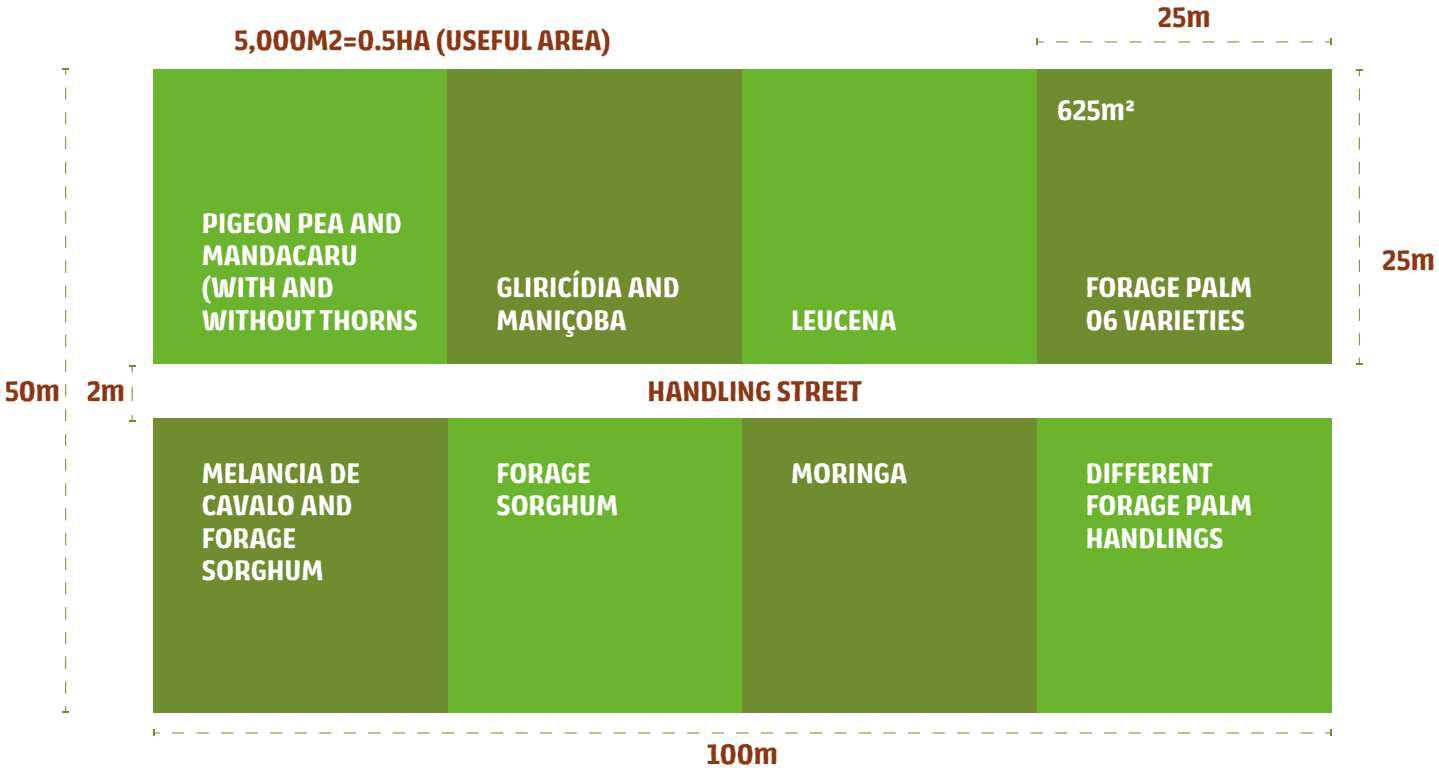
Crop-livestock integration (CLI) involves planned systems with time and space interactions at different scales and the exploitation of animals and crops in the same area, simultaneously or at different times, in rotation, intercropping, or succession. The practice started in the South of the country, with rice crops introduced in pasture areas to recover pasture productivity. The CLI system has been used in several regions and is also adopted with other grains such as soy, corn, or sorghum.

The agricultural and environmental benefits include improved soil chemical, physical, and biological properties; reduced occurrence of diseases, pest insects, and weeds; increased plant and animal productivity; reduced dependence on external inputs and limited production loss

Animals grazing after corn harvest.
Credit: José Henrique de Albuquerque Rangel.

In the semiarid, the CLI system involves forage palm, corn, grasses, and forage legumes adapted to the region with cattle or goat raising. For example, an agroecological forage test (Figure 21) was developed with 18 families raising goats, sheep, and chickens and the dryland farmer community of Cachoeirinha, located 70 km from the headquarters of the municipality of Juazeiro-BA. The test diversified native and adapted forage plants: forage palm (6 varieties), leucena, moringa, gliricidia, maniçoba, forage sorghum, pigeon pea, melancia de cavalo (horse watermelon), and mandacaru with and without thorns. In an area of 0.5 ha, divided into eight plots of 25 x 25 m (625 m2), four plots were distributed on one side and four on the other (Figure 21). In addition, a solar-powered water pumping system and a local irrigation system (drip) were used. In the last months, the test result guaranteed the production of 4,750 kg of forage sorghum silage through two cuts and increased food stock for the animals. Moreover, “the diversity of forage plants ensures diversified and nutritious food for the herds” (DE MORAES & DANTAS, 2019, pp. 43).

*Figure 21 - Graph of the diversified forage test**



Left: Implanted crops, Silage production
Note: Forages included native and adapted plants: forage palm (6 varieties), leucena, moringa, gliricidia, maniçoba, forage sorghum, pigeon pea, melancia-de-cavalo, and mandacaru with and without thorns Credit: Victor Leonam - Study Centers in Agroecology and Coping with the Semiarid9 (DE MORAES & DANTAS, 2019)

VISIT LINKS OF INTEREST::

Fruit and sheep intercropping. *https://ainfo.cnptia.embrapa.br/digital/bitstream/CPATSA/8853/1/CTE52.pdf*

Crop-livestock integration: Corn - Massai - Cunha (CMC) system as an alternative for forage production in the Brazilian semiarid region *https://ifce.edu.br/proext/producoes-tecnicas/cartilha-tecnologias-para-o-campo/edicoes/integracao-lavoura-e-pecuaria-sistema-milho-2013-massai-2013-cunha-mmc.pdf*

Crop-livestock integration system under dryland conditions: Guarantee of quality forage reserve in the form of silage for the semiarid region. *https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/1102320/1/CNPC2018Cot180.pdf*

On the other hand, the CLI systems should contemplate the edaphoclimatic characteristics of the semiarid region, which has a rainy season (January to June) and a dry season (July to December). Thus, the planting of the system takes place during the rainy season and the availability of forage produced occurs during the dry season of the year. For example, corn, which is common in semiarid production along with massai (Panicum maximum cv), a drought-resistant grass that allows grazing by small ruminants, plus cunha (Clitoria ternatea), a legume, form the CLI system Corn-Massai-Cunha (CMC) intercropping, which produces forage for sheep and lambs in the Northeastern Semiarid (RÊGO et al, 2019).

Farming Diversification: CROP-LIVESTOCK-FOREST INTEGRATION (CLFI)

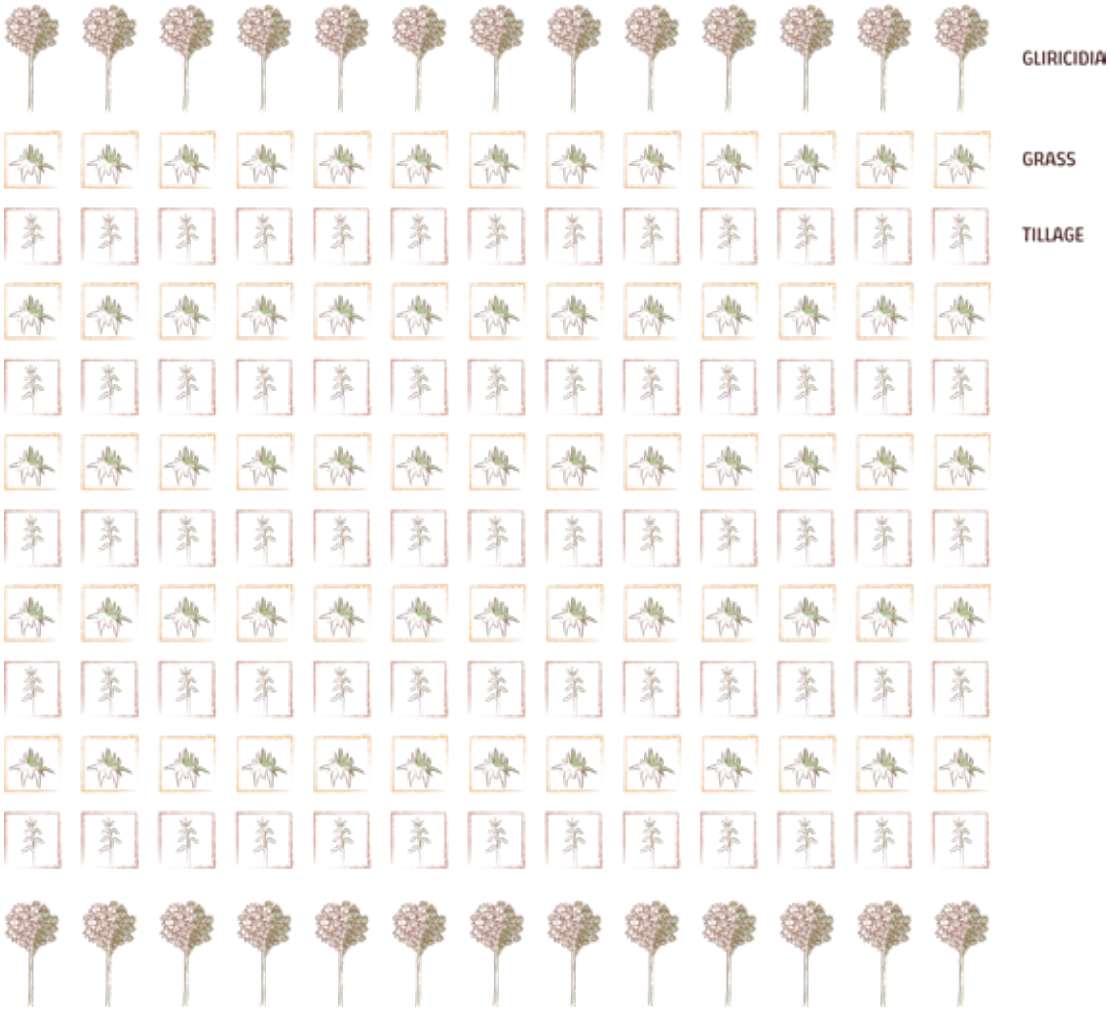
CLFI system - corn with grass between the rows of gliricídia
Credits: José Henrique de Albuquerque Rangel Source: Range et al, 2010

The crop-livestock-forest integration (CLFI) includes crop, livestock, and forest, performed in the same area, in intercropping, succession, or rotation. The crop component can be restricted (or not) to the initial implementation phase of the forest component (RANGEL et al., 2010). The productivity and profitability of CLFI are higher for beef cattle and grain crops compared to traditional production systems. Furthermore, there is an increase in animal welfare.

The use of tree legumes such as leucena (Leucaena leucocephala) and gliricídia (Gliricidia sepium) in CLFI systems has been highlighted in the semiarid regions of Brazil. For example, Gliricidia can be cultivated intercropping with crops (corn, sorghum, or millet) and pastures (Brachiaria brizantha, B. decumbens, Brachiaria ruziziensis, B. humidicola or Urochloa mossabicencis). Thus, gliricídia can be a food supplement in the dry season. However, the grazing of animals (not monogastric[6]) should begin in the first year to avoid trampling the young plants (RANGEL et al., 2010)

6 *Monogastric animals, such as donkeys or horses, can have problems with the consumption of gliricídia.*

Figure 22 - Graph of the CLFI setup with Gliricidia for mechanical planting



Source: Rangel et al, 2010.

VISIT LINKS OF INTEREST:

Agrosilvopastoral system with goats and sheep
https://www.embrapa.br/contando-ciencia/cultivos/-/asset_publisher/SQBdWkKUgS0N/content/sistema-agrossilvipastoril/1355746?inheritRedirect=false

Agrosilvopastoral production system at Embrapa Goats and Sheep (located in Sobral, in the countryside of Ceará)
https://www.embrapa.br/contando-ciencia/cultivos/-/asset_publisher/SQBdWkKUgS0N/content/sistema-agrossilvipastoril/1355746?inheritRedirect=false

Sowing Technological Innovation: Experiences of socioeconomic development in the Northeastern Semiarid
http://portalsemear.org.br/publicacoes/semeando-inovacao-tecnologica-experiencias-de-desenvolvimento-socioeconomico-no-semiarido-nordestino/

Crop-livestock-forest integration in the Northeast Region of Brazil
https://ainfo.cnptia.embrapa.br/digital/bitstream/item/167485/1/2017-053.pdf

Implementation and management of Crop-Livestock-Forest integration system with gliricídia sepium
https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/878448/1/ct60.pdf

Box 2

Technologies for the Management and Enrichment of the Caatinga*

Protein banks

Protein banks are plantations with forages with high protein levels, such as leucena, gliricídia, and pigeon pea, among others (see Table 1), which serve as a supplement in the feeding of goats, especially for animals in the fattening or lactation phase. It is recommended that goats or sheep graze only one or two hours a day in protein banks with a small area. However, protein banks can be intercropped with forage palms to make cuts and give to animals in natura, silage, or hay.

Table 1 - Native and adapted plants with high nutritional values

Common name	Cientific name	Gross Protein (%)
Catingueira (pau de rato)	Caesalpiniapyramidales	12.0
Faveleira	Cnidoscolusphyllacanthus	18.5
Gliricídia	Gliricidiasepium	23.0
Jitirana	Merremiaaegyptia L.	20.8
Jureminha	Desmanthusvirgatus (L.) Willd.	28.7
Leucena	Cnidoscolusphyllacanthus	21.0
Mandacaru**	CactaceaeCereus jamacaru DC	15.5
Mandioca-brava or Maniçoba***	Manihotesculentaranz	20.0
Mata-pasto****	Senna obtusifolia	18.1

Source: (ARAUJO; DA SILVA; SANTANA, 2015)
***The thorns of the mandacaru should be removed before feeding the animals.*
****Mandioca brava should be hayed because in natura can cause intoxication by hydrocyanic acid*
***** It is better to hay the mata-pasto, since it has low palatability for having a bitter taste.*

Haymaking

Haymaking is the process of conserving forage plants by drying them in the sun, and spreading them in the field, shredded or not, for several days, depending on the type of plant. In the case of haymaking with Catingueira leaves, some of the more peripheral branches can be cut, less than 50% of the crown. In this case, after three days, the hay can be stored to feed the animals during the dry season. It is important to avoid many days of drying, as this can compromise the hay's nutritional value. If, when twisting the leaves, they break into crumbs, the drying has already been excessive.

** This topic is part of the booklet "Sowing Technological Innovation: Experiences of socioeconomic development in the Northeastern Semiarid" (ARAUJO; DA SILVA; SANTANA, 2015).*

Farming diversification: MIXED FARMING SYSTEMS

Mixed farming systems (MFS) basically consist of the coexistence of agricultural crops and livestock activities on the same farm. The difference to CLI is that mixed farming systems do not necessarily have the exploitation of crops and livestock in the same area, but in the same establishment. In mixed systems, animal husbandry, in addition to producing meat, fiber, eggs, milk, or other animal products, also helps provide nutrients for crops and soil microorganisms with their waste. This complementarity between agriculture and livestock occurs when their exploitation generates different products but is linked to products from one activity, which is, in turn, supply for the second activity.

In the province of Santiago del Estero, in the Semiarid Chaco[7] of Argentina, goat raising appears as a feasible alternative in arid regions through the knowledge of native forage resources. At the same time, the animals' manure fertilizes the grazing soil (GRIMALDI; CILLA; MOREND, 2019.)

Backyard with chicken raising - Semear Project - Credit William França

Delivery of goat pens and goats_Com_Pitombeira_ Mun.Tauá_CE_Collection PPF

7 7 El Chaco Semiarid, with precipitation between 500 and 750 mm per year, has borders with Bolivia, Paraguay, and Argentina (SEMIARIDS PLATFORM, 2021)

Farmers in the rural communities of Sombras Grandes and Milagres, located in the municipality of Caraúbas, in the Chapada do Apodi, in the semiarid region of Rio Grande do Norte, have installed several vegetable and fruit growing systems with irrigation, integrated with animal husbandry and beekeeping. Besides vegetables and fruits, the families also grow cotton, sesame, peanuts, and sorghum. They raise chickens, bees, and goats. There is a protein bank in the communities to sustain the animals. These diversified systems with agroecological practices have been resilient to droughts, as well as maintaining soil fertility. In this way, they produce 16 different types of food and process the fruit into pulp, contributing to the families' food security and food sovereignty. In addition, surpluses are commercialized at the Caraúbas' Agroecological Fair (RN) and in the sale of baskets of agroecological products with delivery to the homes of consumers in Mossoró (Inventory of good practices, IFAD, 2019).

Diversified cropping - Agroecological irrigated systems municipality of Caraúbas, RN.

B. NON-FARMING DIVERSIFICATION WITHIN THE FACILITY

The non-farming activities within the establishment are those that "successively or simultaneously" complement the farming activities, for example:

- Tourism services
- Food services
- Food and fiber processing activities (agroindustry)
- Mineral exploitation
- Handicraft activities in clay, straw, fiber, lace weaving, etc.

In the Northeastern Semiarid, non-farming activities within family farming establishments correspond, on average, to approximately 4% of total income. Figure 23 shows the percentage of these activities by state in 2017. Notably, in almost all states, except Piauí and Bahia, agroindustry products have the highest percentage. Then follow disinvestments, which vary between 35% and 58%. Thus, revenues obtained from rural tourism services contributed, on average, around 13%, with the highest percentage (24%) in the state of Bahia, and the lowest, in Maranhão, with 3%. Finally, handicraft and weaving activities contributed little: in Piauí, Ceará, Paraíba, and Bahia they had participation of approximately 1%. However, these activities have the potential to grow. Handicrafts in clay, straw, fiber, lace weaving, making clothes, blankets, etc. have been significant, especially in women's associations, such as the Group of Potters from Salgado - Andorinha, which produces ceramics, or the Group of Handicraft Makers United to Win from Umbiguda in Mirangaba-BA.

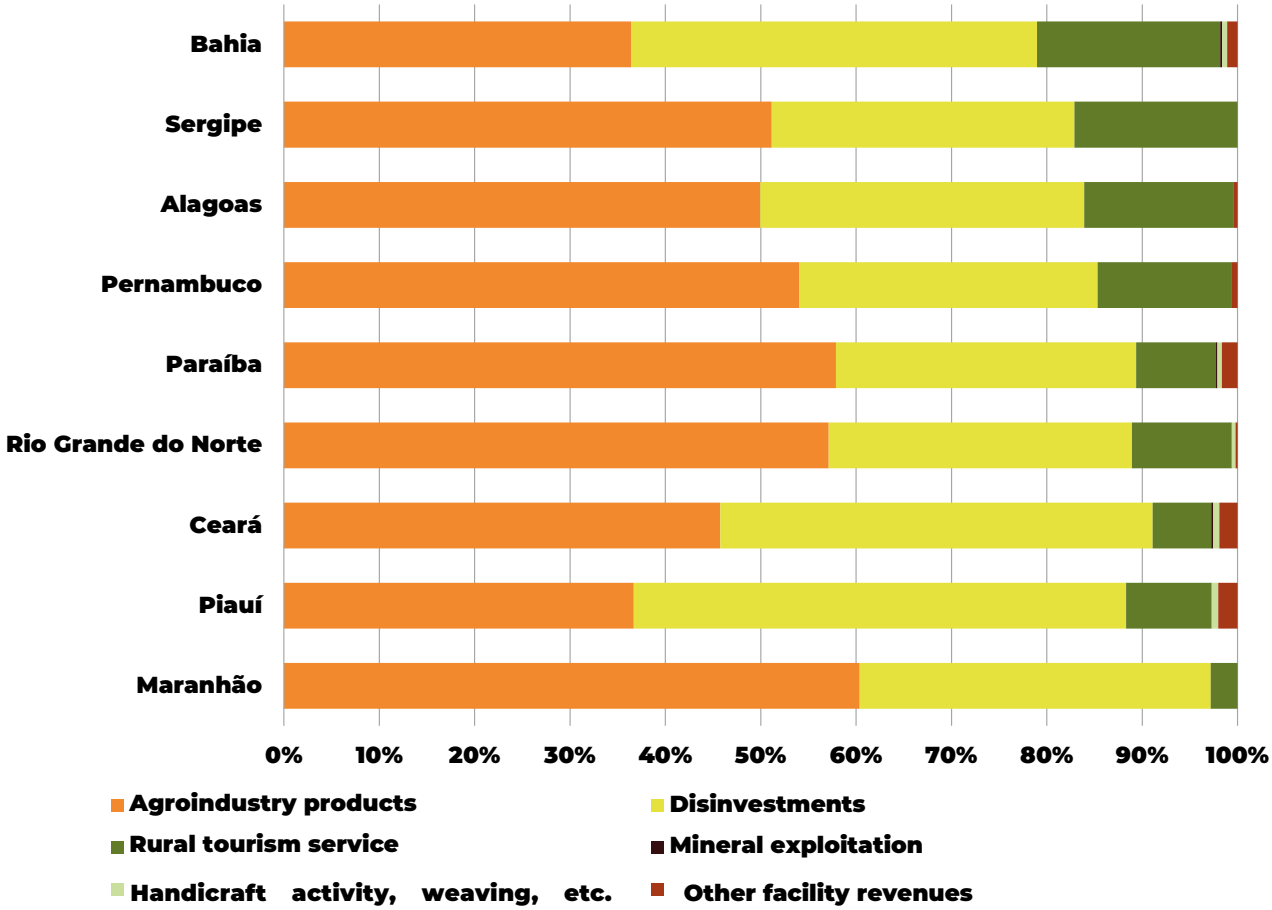
Photo_2b_Dom Távora_Sergipe_Handcrafts_ Neopolis

Group of Potters of Salgado - Andorinha- Credits Manuela Cavadas

Procase Renaissance Lace - Cacimbinha São João do Tigre

Group of Handicraft Makers United to Win from Umbiguda in Mirangaba-BA - Photo - Eduardo Rodrigues

Figure 23 - Graph of the percentage of income from non-agricultural activities within the family farming facility in the Northeastern Semiarid States (2017)



Source: IBGE, Farming Census

Box 3

Rural Tourism in Paraíba's experiences

Rural tourism helps to diversify income in rural areas since it can complement the income from farming activities on the property. In addition, rural tourism values the sociocultural and natural assets of rural communities. To illustrate, ventures such as pick and pay, fish and pay, visits to agro-industrialization or handicraft processes, and food services are part of rural tourism. These activities encompass the knowledge and traditions of the rural population. In this context, several experiences in rural tourism in Paraíba have been systematized in the booklet "Seeds of Hope*: good practices of coping with the semi-arid region - Tourism and Rural Youth". Thus, two rural tourism enterprises with greater inclusion in community-based actions will be presented:

Vila Real Flowers Project

O Projeto Flores Vila Real da Associação de Desenvolvimento de Macacos e Furnas The Vila Real Flowers Project of the Development Association of Macacos and Furnas ADESMAF (Women Flower Producers Group) is a venture of a group of young people who produce flowers and have been receiving visitors on site since 2004. It is located in the city of Areia, known for its cultural riches, such as the Pedro Américo Museum and the Rapadura (brown sugar candy) Museum, inside the Campus of the Federal University of Paraíba - UFPB. The income comes from the fee paid by visitors and the sale of flowers, either on the spot or the sales made in other parts of the market.

Association for the Sustainable Development of the Chã do Jardim Community - ADESCO

In the town of Areia, the Association for the Sustainable Development of Chã de Jardim - ADESCO, since 1996, was articulated by a group of young people from the community to set up several projects, such as the pulp mills and trails (2006), handicrafts with banana leaves (2008), and the rural restaurant (2013). However, the Vó Maria Rural Restaurant is central to the association's rural tourism activities. First, because it offers typical regional food, whose raw material is produced by the agro-ecological farming families of the community. Then, because it offers visits to the pulp production line with seasonal fruit. In addition, it features trails and picnics in the Pau Ferro environmental reserve, as well as handicraft activities with banana leaves. At the restaurant, the number of meals went from 200 lunches per week when the site opened to 1,250 meals per week today. The Association has obtained partnerships with the State Government through PROCASE, SEBRAE, UFPB, SENAR and BNB.

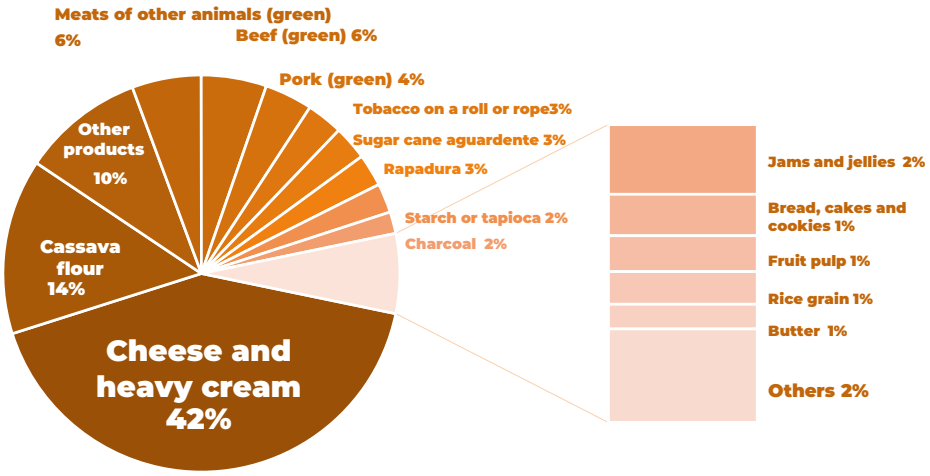
Rural Restaurant Vó Maria - Community Chã do Jardim. Picnic at Pau Ferro Woods - Community Chã do Jardim. Credits: PROCASE (2019).
** This booklet brings together five good practices for coping with the semiarid that are linked to rural tourism processes. The work is the result of a partnership between Semear International, Procasur and IFAD beneficiaries served by the Procase Program in Paraíba (IFAD, 2019).*

i. Agroindustry diversification in the northeastern semiarid

Photo_4c_Dom Távora Project_pov_Cacimba Nova_Poço Verde_ SeagriSE
Bahia Prosemiarid Project Coopercuc process of making passion fruit jam from the forest Uaua Bahia14- credit Fernando Falcão
Production Group Tia Likinha Biscuit, community várzea Queimada, Caém - BA - Photo - Manuela Cavadas Mascavo - Viva o Semiárido Project

As agroindustry was the most representative activity and has available data, Figure 24 presents its disaggregated products in 2017. The main product in the agroindustry of farming families in the Northeastern semiarid is cheese or requeijão (similar to cream cheese). This includes that the main livestock product is milk (Figure 24). Right behind is cassava flour (14%), followed by other unspecified products (10%). Furthermore, the sale of various types of meat, such as pork or beef, represents around 15% of the total value in the agroindustry. Sugar cane products, such as rapadura (brown sugar candy) and aguardente (sugarcane spirit), account for about 6% of the total value. In the last portion, there are Others (2%), which includes all products with less than 1% participation. These other products are fruit juices, cajuína (cashew beverage), treated meat (sun-dried, salted), wood products, vegetable oils, roasted and ground coffee, molasses, roasted coffee beans, heavy cream, corn flour, hides and skins, sausages, etc., processed vegetables, liqueurs, cotton lint, cottonseed, and grape wine. For more detail by state, see Annex 6.

Figure 24 - Chart of the percentage of the total of family farming agroindustry in the Northeastern Semiarid (2017)



Source: IBGE, Farming Census

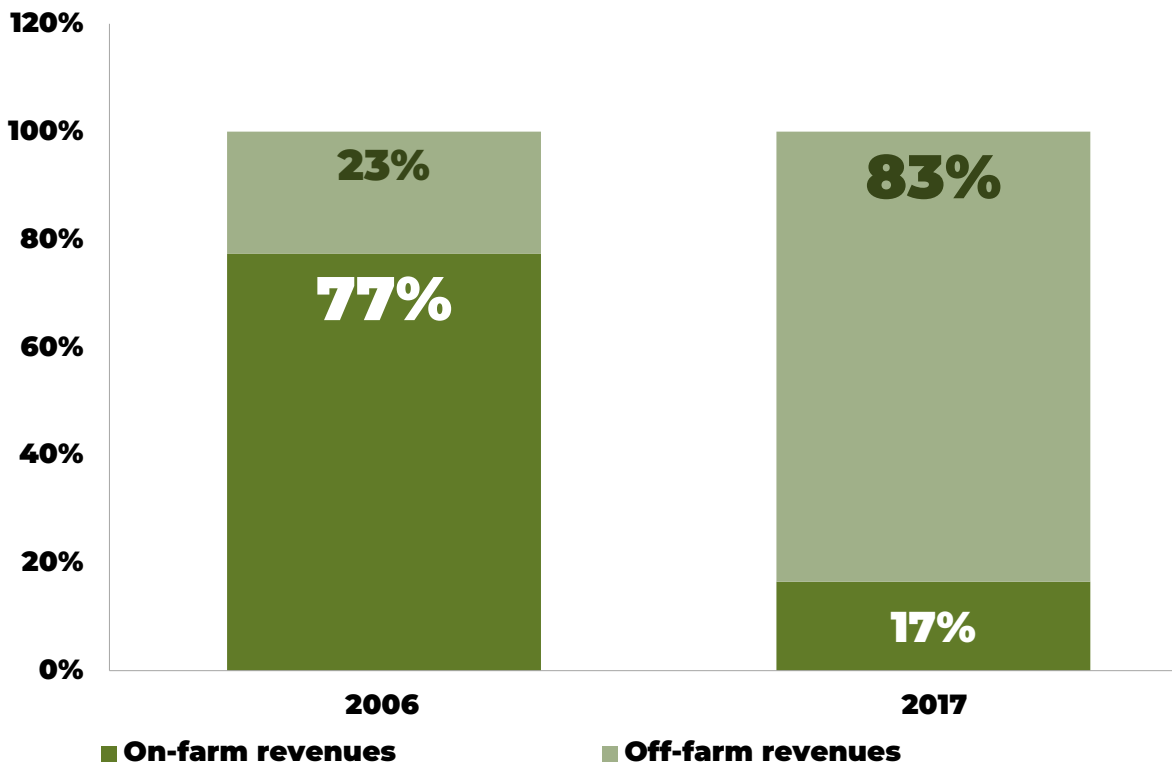
Although there is little participation (1%) of fruit pulp, some experiences have shown its potential in generating income for farmers, such as the Family Farmers of the Forquilha Valley Cooperative (Coopvale), in the city of Quixeramobim, CE. In this business venture, farmers could take advantage of fruits that were sometimes wasted or of low quality by processing pulp. The cooperative is formed by 62 families who supply processed fruit to supermarkets, snack bars, and 50 schools. The pulp is supplied to schools through the Family Agriculture Food Acquisition Program (PAA) and the National School Meals Program (PNAE). The gross income from selling fruit pulp to schools between 2017 and 2018 was a little over a million reais (Brazilian currency/BRL). The project was partnered with the Paulo Freire Project, implemented by the IFAD in Ceará (IFAD, 2019).

C. DIVERSIFICATION OUTSIDE THE FACILITY

Off-farm diversification is related to pluriactivity, a strategy used by rural families, in which some family member articulates with the agricultural or non-agricultural labor market (SCHNEIDER, 2001). Off-farm agricultural activities vary from fixed and temporary jobs in third-party establishments to renting land or equipment. On the other hand, the incomes of non-farming activities outside the facility include self-employment or salaried work in commerce and services, as well as resources from retirement or pensions and social programs (Federal, State, or Municipal Government).

Figure 25 shows that on-farm income was higher than off-farm income in 2006. In 2017, this relation is reversed, as off-farm income increased, at 83%.

Figure 25 - Chart of on- and off-farm revenues for family farming in the Northeastern Semiarid (2006 and 2017)

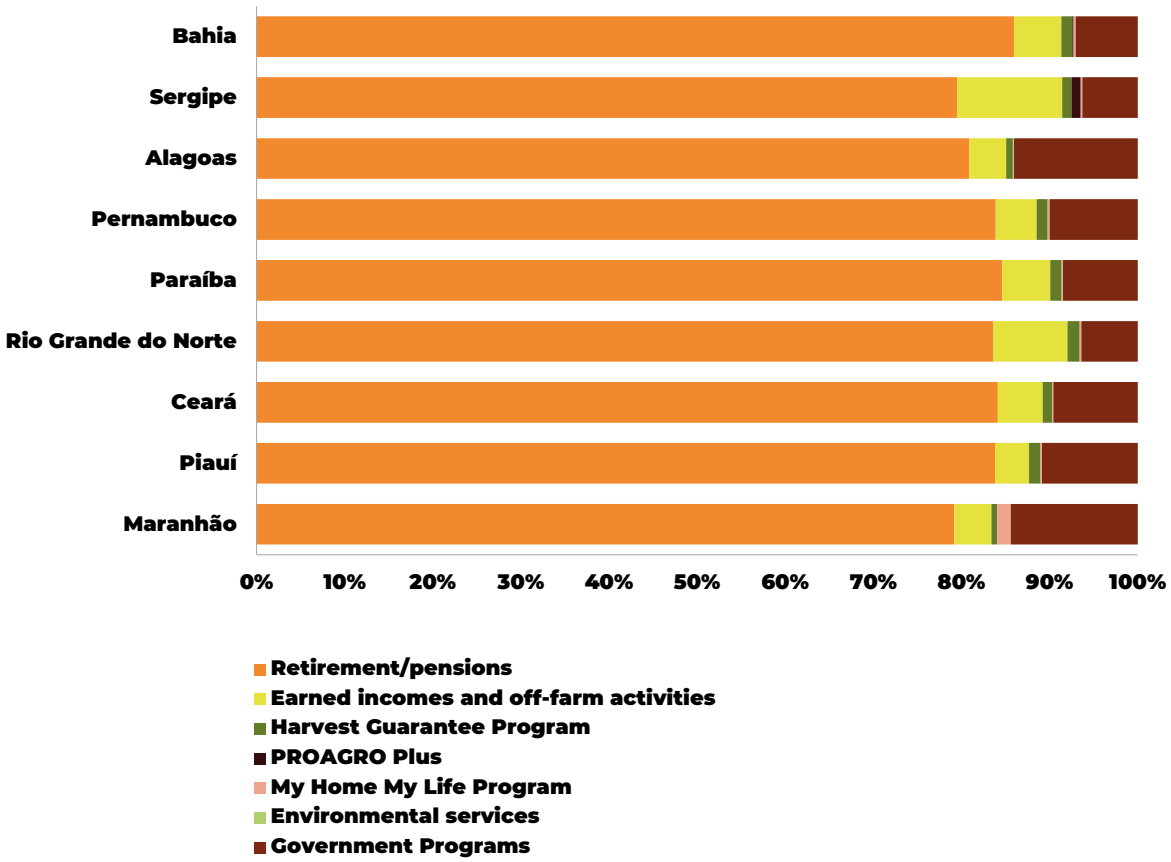


Source: IBGE, Farming Census 2006 and 2017 .

** In the 2006 Farming Census, the state of Maranhão was not part of the semiarid.*

According to Figure 26, all Semiarid states presented retirements or pensions as their primary offsite income in 2017. In most states, these resources exceeded 79%. Then, it is followed by revenues from other government programs (Federal, State, or Municipal), including Bolsa Familia (conditional cash transfer program), which varies between 6% and 14%. Then, in third place of importance, follow the incomes obtained in activities outside the facility, with Sergipe having the highest percentage, with 12%. The programs Harvest-Guarantee and Guarantee for the Agricultural Activity of Family Farmers (PROAGRO Plus), the National Rural Housing Program Minha Casa Minha Vida (My Home My Life), as well as the payment for environmental services (Bolsa Verde (Green Grant) and State Programs), had minimal participation in family farming in the Northeastern Semiarid.

Figure 26. Revenues obtained outside the family farm facility of the Northeastern Semiarid states (2017)



Source: IBGE, Farming Census

FINAL REMARKS

The booklet FARMING DIVERSIFICATION aimed to facilitate access to technical farming information on the great diversity of farming production and social reproduction in the rural area of the Brazilian Northeastern Semiarid. It can be noted that most municipalities in the semiarid region present diversified agriculture, with values above 0.69 in the Simpson indexes for agricultural diversification. The products of livestock activity are the main ones (highlighting the bovine milk and cattle production), followed by the production of temporary crops (corn, cassava, beans). Then follow the products of permanent farming, mostly with bananas, mango, and passion fruit. The products of vegetable extraction and horticulture follow in importance. Aquaculture stands out in almost all the Northeastern states except Alagoas and Pernambuco. The production of forestry and floriculture had an insignificant participation. In this scenario, there is the possibility of expanding the farming diversity with 186 products, thus increasing the income and food security of farming families in the region. Moreover, the non-farming activities produced on the farms have a high potential to diversify families' income, although they contribute approximately 4% of the total income. For example, the agroindustry, which had the highest participation in this category, offers more than 33 products, of which dairy products stand out.

On the other hand, most states in the region depend mainly on income from non-farming activities outside the rural facility, especially retirements and pensions. However, there is the possibility of diversifying income through articulating farming family members with the region's farming or non-farming labor market.

Thus, in general, it is noted that farming families in the Northeastern Semiarid vary their activities within the establishment. Thus, there is the possibility of increasing the sources and forms of access to income, helping to reduce the variability of the farmer's income, especially to minimize vulnerability to adverse weather effects

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GLOSSARY

Green Grant (Bolsa Verde): The Environmental Conservation Support Program is a Federal Government cash transfer program, established by Law 12,512, October 14, 2011, and regulated by Decree no. 7,572, September 28, 2011. The program is aimed at families in extreme poverty, registered in the Unified Registry for Social Programs of the Federal Government, and who develop environmental conservation activities in the following areas: (a) national forests, federal extractive reserves, and federal sustainable development reserves; (b) forest, sustainable development or agroextractive settlement projects established by INCRA; (c) territories occupied by riverine, extractive, indigenous populations, quilombolas, and other traditional communities; and (d) other rural areas defined as priorities by an act of the Executive Branch (MINISTRY OF ENVIRONMENT, 2012). The implementation of the program is the responsibility of the Ministry of Environment - MMA, which is responsible for defining the complementary rules of the program, and Caixa (bank) is the operating agent.

Extreme events: includes droughts, floods, tornadoes and windstorms, heat waves, frosts, cyclones, rough seas, etc.

Pluriactivity: strategy used in farming establishments, in which some member of the family articulates with the farming or non-farming labor market

Harvest Guarantee Program (Garantia-Safra): aims to ensure food security for family farmers living in regions systematically subject to crop loss due to drought or floods. Farmers with a monthly income of up to one and a half minimum wages are entitled to receive the benefit when they have lost 50% or more of their production. The benefit amounts to BRL 850, divided into five BRL 170 installments. The crop guarantee is available according to the social benefits payment calendar (CAIXA ECONOMICA, 2020).

Proagro Plus Program (Proagro Mais): The Agricultural Activity Guarantee Program of Family Farming financially helps the farmer negatively affected by natural phenomena, pests, and diseases. The form of the aid can be: a) exemption from financial obligations related to rural credit operation for costing and installments of rural investment credit; b) compensation for own resources used by the producer; c) guarantee of minimum income from production linked to rural costing (BANCO CENTRAL DO BRASIL, 2021, p. 5).

Resilience: Ability to adapt to bad weather, change or misfortune. It is the ability of a system, community, or society exposed to some threat to resist, absorb, adapt, and recover from its effects in a timely and effective manner, including preserving and restoring its basic structures and functions. A community's resilience depends on the resources it needs and the ability to organize itself to prevent and act against possible risk events.

ANNEXES

Annex 1 - Chart of the percentage of the total family farming products by states in the Northeastern Semiarid (2017)

State	Milk	Cattle	Chicken eggs	Pigs	Sheep	Cattle Slaughte-ring	Chicken	Goats	Cattle Raising	Honey	Cattle bree-ding	Horses	Others
Maranhão	15.3%	29.6%	10.3%	24.0%	3.8%	1.3%	12.0%	2.6%	-	-	0.2%	0.9%	-
Piauí	28.7%	20.7%	10.7%	8.2%	7.8%	3.5%	5.0%	5.5%	1.0%	6.3%	1.0%	1.0%	0.6%
Ceará	45.5%	19.0%	10.8%	8.2%	3.9%	3.4%	3.3%	1.8%	1.0%	1.4%	0.9%	0.7%	0.3%
Rio Grande do Norte	38.1%	30.1%	8.1%	4.3%	4.5%	2.9%	4.4%	2.2%	1.3%	0.4%	0.8%	2.1%	0.7%
Paraíba	31.8%	33.6%	7.1%	4.9%	3.1%	3.7%	7.6%	3.0%	1.2%	0.2%	0.9%	1.5%	1.6%
Pernambuco	39.1%	29.5%	8.0%	4.4%	4.5%	2.4%	4.6%	3.5%	1.0%	0.2%	0.8%	0.9%	1.1%
Alagoas	42.3%	35.2%	5.3%	4.1%	4.2%	2.6%	1.1%	0.7%	0.8%	0.2%	1.4%	1.1%	1.0%
Sergipe	45.1%	32.7%	3.4%	3.5%	2.6%	4.5%	2.7%	0.5%	2.1%	0.1%	1.4%	1.3%	0.2%
Bahia	27.9%	36.2%	7.3%	4.8%	5.7%	6.2%	2.4%	3.1%	2.8%	0.9%	1.3%	0.8%	0.7%

**Note: Others include the following livestock products: goat's milk, quail eggs, mules, quails, donkeys, beeswax, sheep's milk, royal bee jam, bubaline heads, bubaline milk, rabbits, sheep's wool. Source: IBGE, Farming Census 2017.*

Annex 2 - Chart of the Percentage of the Total Temporary Crop Products of Family Farming by States of the Northeastern Semiarid Region (2017)

State	Corn grain	Cassava, aipim, macaxeira (different names for cassava)	Cowpea Grain	Forage Palm	Forage Corn	Watermelon	Colored bean grain	Sugar cane	Tomato	Pineapple	Jerimum pumpkin	Onions	Husked rice	Green bean	Dry leaf tobacco	Forage for cutting	Others
Maranhão	9.9%	63.5%	3.8%	-	-	6.3%	0.6%	2.8%	-	-	1.9%	0.0%	6.0%	3.1%	-	1.6%	0.6%
Piauí	33.8%	17.2%	23.0%	0.0%	0.6%	7.8%	0.2%	3.4%	-	0.0%	3.0%	0.0%	9.2%	0.3%	0.0%	0.2%	1.3%
Ceará	35.3%	19.5%	26.3%	0.2%	0.5%	2.0%	0.2%	2.1%	0.1%	0.1%	1.7%	0.0%	2.5%	1.6%	0.0%	0.9%	7.1%
Rio Grande do Norte	13.1%	32.0%	12.3%	2.7%	0.4%	5.4%	0.5%	3.5%	0.7%	4.8%	1.6%	0.9%	1.6%	5.7%	-	4.8%	10.0%
Paraíba	20.6%	8.9%	12.5%	18.3%	0.6%	1.4%	3.2%	4.1%	1.2%	12.9%	2.7%	0.2%	0.9%	2.2%	-	2.6%	7.6%
Pernambuco	18.7%	20.4%	8.2%	12.2%	5.8%	6.1%	4.4%	1.6%	2.5%	1.7%	3.6%	2.2%	0.3%	2.1%	-	1.0%	9.0%
Alagoas	21.5%	11.3%	2.7%	16.7%	9.0%	0.1%	13.2%	0.1%	0.0%	1.7%	1.5%	-	-	1.4%	19.3%	0.1%	1.5%
Sergipe	31.7%	4.9%	0.4%	17.8%	33.5%	0.0%	2.8%	0.2%	1.5%	2.1%	0.8%	-	2.6%	0.6%	0.0%	0.1%	0.7%
Bahia	14.6%	19.2%	4.2%	13.9%	2.6%	4.8%	6.9%	6.6%	6.8%	2.4%	2.3%	5.0%	0.1%	1.7%	0.7%	0.6%	7.6%

Note: Others include the following temporary crop products: Fava bean grain, Other products, Forage sorghum, Castor bean, Melon, Black bean grain, Herbaceous cotton, Garlic, Peanut husk, Potato, Pea grain, Sesame, Sunflower, Rami fiber, Soybean grain, Sorghum grain, Broom sorghum, Forage sugar cane, Cotton seed, Rice seed, Bean seed, Corn seed, Forage seed, Sugar cane billets, Other products seed.
Source: IBGE, Farming Census 2017.

Annex 3 - Chart of the percentage of the Total Value of Permanent Crop products from family farming by Semiarid states (2017)

State	Banana	Mango	Cashew chestnut	Passion fruit	Bahia coconut	Agave sisal (fiber)	Arabica coffee green	Table grape	Guava	Acerola	Cashew fruit	Cocoa almond	Other products	Orange	Papaya	Agave (leaf)	Sugar apple	Lemon	Other
Maranhão	9.6%	-	51.2%	-	-	-	-	-	-	-	39.2%	-	-	-	-	-	-	-	-
Piauí	19.2%	0.5%	38.0%	0.8%	1.5%	-	-	-	0.1%	6.0%	31.9%	-	0.8%	0.5%	0.4%	-	0.1%	0.2%	-
Ceará	32.3%	0.6%	33.7%	7.2%	10.7%	-	0.1%	0.0%	1.3%	2.1%	3.0%	-	4.9%	0.2%	1.2%	-	0.0%	1.7%	1.1%
Rio Grande do Norte	36.2%	2.1%	26.9%	7.3%	6.2%	-	-	-	0.4%	1.1%	8.2%	-	0.2%	0.0%	9.4%	-	1.9%	0.0%	0.1%
Paraíba	70.9%	0.4%	0.7%	6.4%	3.1%	1.1%	-	1.9%	0.6%	0.5%	0.6%	-	0.1%	2.1%	0.7%	0.2%	0.1%	0.8%	9.9%
Pernambuco	38.4%	11.8%	0.4%	3.0%	6.1%	0.0%	0.1%	16.4%	9.9%	8.4%	0.8%	-	0.8%	0.9%	1.2%	-	0.1%	1.2%	0.7%
Alagoas	42.0%	0.5%	0.8%	2.5%	0.9%	-	-	-	0.1%	-	3.3%	-	37.5%	2.4%	1.5%	-	8.2%	-	0.3%
Sergipe	46.5%	5.3%	-	5.7%	4.8%	-	-	-	13.2%	22.5%	0.2%	-	-	1.7%	-	-	-	-	-
Bahia	27.8%	14.3%	0.9%	12.0%	6.4%	12.1%	11.4%	1.4%	1.1%	0.3%	0.3%	3.7%	0.5%	2.2%	0.9%	2.0%	1.5%	0.5%	0.6%

Note: Others include the following permanent crop products: Tangerine, Avocado, Annatto (seed), Soursop, Jackfruit, Black pepper, Atemoia, Jabuticaba, Coffee canephora (robusta, conilon) in grain (green), Pomegranate, Guaraná, Açaí (fruit), Grape (wine or juice), Cupuaçu, Dendê (coconut), Rubber (coagulated latex)
Source: IBGE, 2017 Agricultural Census.

Annex 4 - Chart of the percentage of the Total Horticulture products by Semiarid states (2017)

State	Cilan-tro	Lettuce	Staked Tomato	Sweet potato	Chives	Corn on the cob	Pe-pper	Carrot	Okra	Chayo-te	Kale	Strawberry	Chili pepper	Beet	Cucum-ber	Ca-bbage	Maxi-xe	Others
Mara-nhão	23.2%	-	-	0.1%	44.9%	2.2%	0.2%	-	22.8%	-	-	-	1.0%	-	-	-	5.5%	0.0%
Piauí	35.7%	12.0%	3.9%	0.8%	28.3%	4.0%	1.8%	0.1%	2.3%	-	3.4%	-	2.5%	0.1%	0.2%	-	1.4%	3.4%
Ceará	21.3%	11.3%	11.5%	7.4%	17.1%	5.0%	9.9%	0.6%	0.8%	2.0%	0.9%	-	3.4%	0.3%	2.0%	0.4%	0.5%	5.5%
Rio Gran-de do Norte	18.7%	10.6%	3.0%	41.3%	2.9%	13.2%	4.1%	0.4%	0.8%	-	1.3%	-	0.7%	0.2%	0.0%	0.0%	0.3%	2.5%
Paraíba	24.1%	16.4%	3.3%	19.7%	3.3%	6.2%	7.6%	0.1%	1.2%	-	3.2%	-	0.2%	0.1%	0.2%	1.5%	0.5%	12.3%
Pernam-buco	20.8%	13.2%	1.6%	7.2%	4.2%	14.8%	7.1%	1.6%	2.7%	7.3%	3.5%	0.1%	0.4%	0.5%	1.7%	3.6%	1.2%	8.4%
Alagoas	57.1%	19.2%	1.1%	3.1%	5.2%	0.5%	2.9%	0.2%	1.5%	0.0%	5.4%	-	0.7%	0.0%	-	0.2%	0.4%	2.6%
Sergipe	5.6%	6.8%	1.0%	17.4%	0.6%	18.4%	4.6%	-	35.9%	-	4.3%	-	3.9%	0.0%	-	0.1%	0.4%	1.2%
Bahia	9.7%	11.1%	13.4%	3.5%	3.4%	4.8%	7.0%	9.5%	4.9%	5.5%	3.4%	7.9%	0.7%	3.3%	1.5%	0.8%	1.2%	8.4%

Note: Others include the following horticultural products: Yams, Jiló, Cauliflower, Eggplant , Arugula, Broccoli, Zucchini , Parsley, Cará, Chard, Pods (string beans), Other products, Mint, Spinach, Seedlings and other forms of propagation (produced for planting), Baroa potatoes (mandioquinha), Seeds (produced for planting), Leek, Fennel, Basil, Watercress, Radish, Rosemary, Celery, Ginger, Mustard (seed), Turnip, Chicory, Malabar spinach, Strawberry, Boldo, Vegetable sponge, Chamomile, Pea (pod), Taioba.
Source: IBGE, Farming Census 2017.

Annex 5 - Table of the percentage of the Total Vegetable Extraction products of family farming by Semiarid states (2017)

State	Wood	Other products	Wood in logs for other purpose	Carnaúba straw powder	Babassu coconut	Imbú/ Umbú	Pequi	Licuri coco-nut	Wood for paper-making	Buriti coconut	Car-naúba wax	Caja-rana	Babassu almond	Man-gaba fruit	Others
Maranhão	3.3%	-	22.2%	36.8%	31.5%	-	0.4%	-	-	0.1%	-	0.8%	4.9%	-	0.1%
Piauí	39.3%	1.1%	9.3%	40.7%	7.2%	0.2%	0.2%	-	-	1.4%	-	0.0%	0.4%	-	0.1%
Ceará	50.2%	5.5%	34.4%	7.8%	0.5%	-	1.0%	-	-	0.0%	0.6%	0.0%	-	-	0.0%
Rio Grande do Norte	17.7%	4.3%	71.2%	3.3%	-	0.7%	-	-	-	-	1.1%	0.8%	-	0.9%	-
Paraíba	94.3%	0.1%	5.1%	0.0%	-	0.3%	-	-	-	-	-	0.2%	-	-	-
Pernam-buco	87.1%	-	12.4%	-	-	0.1%	-	-	-	-	-	0.4%	-	-	-
Alagoas	99.4%	-	-	-	-	0.1%	-	0.1%	-	-	-	0.4%	-	-	-
Sergipe	100.0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bahia	25.1%	61.9%	8.5%	-	0.1%	1.9%	0.1%	1.0%	0.9%	0.2%	-	0.1%	0.0%	0.1%	0.1%

Note: Others include the following horticultural products: Licuri (wax), Buriti (straw), Murici, Bacuri, Macaúba (fruit), Araticum (fruit), Cagaita (fruit).
Source: IBGE, Farming Census 2017.

Annex 6: Chart of Percentage of the Total Family Farm Agroindustry Products by Semiarid states (2017)

State	Cheese and requei-jão	Cassava flour	Other products	Mea-ts of other ani-mals	Beef	Pork	Tobac-co on a roll	Sugar cane aguar-dente	Rapa-dura	Starch/ tapioca	Char-coal	Swee-ts/jam	Bread, cake and cookies	Fruit pulp	Rice grain	Butter	Others
Maranhão	-	85.8%	-	0.3%	2.8%	1.0%	-	-	0.0%	2.6%	2.6%	0.1%	-	-	0.3%	-	4.4%
Piauí	7.9%	11.7%	7.4%	9.8%	8.3%	9.0%	0.0%	4.4%	4.5%	7.6%	6.3%	5.4%	0.4%	0.6%	8.6%	0.2%	7.9%
Ceará	37.7%	14.2%	15.0%	8.3%	4.1%	6.2%	-	0.5%	1.9%	3.6%	2.1%	1.9%	1.8%	1.6%	0.1%	0.2%	1.0%
Rio Gran-de do Norte	36.5%	10.3%	38.8%	0.9%	3.4%	1.2%	-	-	0.6%	1.6%	2.0%	1.1%	0.3%	1.8%	0.0%	0.7%	0.8%
Paraíba	61.4%	3.6%	6.4%	9.1%	7.6%	5.3%	-	0.1%	0.9%	0.2%	2.2%	0.8%	0.3%	0.6%	0.0%	0.7%	0.6%
Pernam-buco	81.6%	7.1%	3.3%	0.8%	1.3%	0.7%	-	-	1.6%	0.3%	1.5%	0.6%	0.1%	0.3%	-	0.3%	0.6%
Alagoas	29.1%	6.6%	2.7%	0.4%	0.9%	-	58.1%	-	-	1.9%	-	0.1%	-	0.0%	-	-	0.3%
Sergipe	69.0%	2.3%	0.3%	3.8%	19.2%	3.0%	-	-	-	-	-	-	-	-	-	1.2%	1.1%
Bahia	24.1%	27.3%	4.9%	6.5%	6.0%	3.3%	0.7%	9.7%	6.1%	2.6%	0.5%	1.6%	1.6%	0.5%	0.0%	1.0%	3.5%

Note: Others include the following agribusiness products: Fruit juices, Treated meat (sun dried, salted), Wood products, Vegetable oils, Ground roasted coffee, Molasses, Roasted coffee beans, Heavy cream, Cornmeal, Hides and skins, Sausages, etc., Vegetables (processed), Liqueurs, Cotton lint, Cottonseed, Grape wine.
Source: IBGE, Farming Census 2017.

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