Public policies for adapting agriculture to climate change in semi-arid Northeast Brazil

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Rio de Janeiro, 2022

e-papers

CHAPTER 4

Sustainable agriculture as an adaptation measure for Araripe Plaster Pole

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Introduction

The Araripe Plaster Pole, located in the Brazilian semi-arid region, is responsible for producing 97% of the gypsum consumed in Brazil, which is considered the best quality gypsum worldwide given its high purity (Barbosa et al., 2014). However, the energy matrix of the factories involved in the gypsum production process in the Araripe region is characterized by firewood use from the Caatinga, most often the result of illegal deforestation. Moreover, monoculture systems, commonly practiced by traditional agriculture in the region, are characterized by predatory extraction of natural resources of soil and vegetation and the consequent oversimplification of the food web, losing the resilience or environmental plasticity of the ecosystem.

The family farmer in the Plaster Pole whose land area is small must produce food on his property (agricultural or livestock) to ensure his food security. The lack of technologies compatible with environmental conservation and adverse climate conditions contribute to the intensifying land use to levels beyond recovery capacity, compromising the socio-economic sustainability of Araripe. Thus, combined with the fragility of the energy matrix, food production through traditional crops can exert negative impacts in the face of climate change scenarios. Models of intercropping and resilient to climate change could ensure food and energy security for the Araripe Plaster Pole. Thus, cropping systems with a multiple and integrated approach can reduce rural system vulnerability and contribute to the social, economic, and environmental development of the Plaster Pole.

Araripe Plaster Pole

The agricultural base of the semi-arid region is family-based, with small establishments. In this region is the Local Productive Arrangement of Gypsum, called the Araripe Plaster Pole (BRASIL, 2018a, AD DIPER, 2020). It comprises the municipalities of Araripina, Bodocó, Cedro, Dormentes, Exu, Granito, Ipubi, Moreilândia, Ouricuri, Parnamirim, Santa Cruz, Santa Filomena, Serrita, Terra Nova, and Trindade (Figure 1).

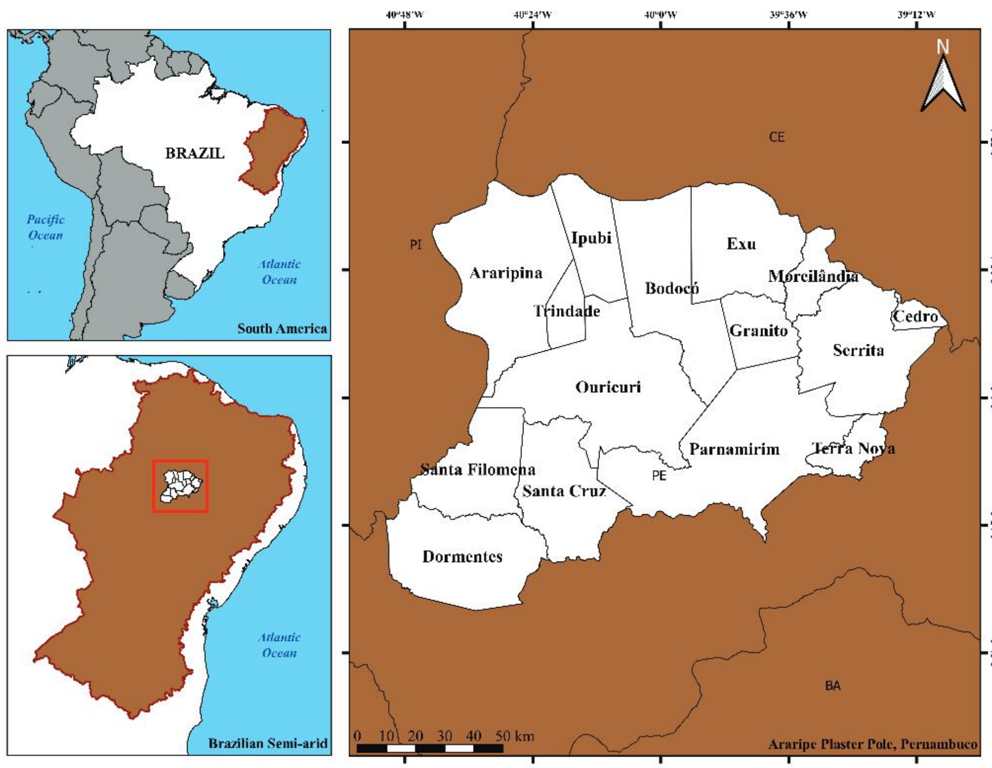

Figure 1. Municipalities that make up the Araripe Region in the Brazilian semi-arid region.

According to Barbosa et al. (2014), the gypsum from the Araripe Plaster Pole is highly pure (80% to 95%) of outstanding worldwide quality. Its importance, apart from the production relevance, is demonstrated by the number of direct and indirect jobs and production chain movement. In the Araripe Plaster Pole, about 40 thousand jobs are generated, resulting from 150 calcination industries, 35 mining companies, and 400 enterprises that manufacture precast gypsum products (BRASIL, 2018a; SITÔNIO, 2019; AD DIPER, 2020). The extraction and processing of gypsum are the most relevant economic activities in the Araripe backlands, generating more than R$70 million per year-1 (AD DIPER, 2020). The entire production chain generates approximately R$ 1.4 billion per year-1

(SINDUSGESSO, 2014). In 2017, the Plaster Pole produced 1.68 million gross tons of gypsum, processing 741 thousand tons (BRASIL, 2018b).

The energy matrix of the factories involved in the gypsum production process in the Araripe region is firewood from the native forest (Caatinga), obtained largely without due observation of the current legislation. In a Webinar held by the Brazilian Service of Support to Micro and Small Enterprises (Sebrae) of Pernambuco in August 2020, the president of the Union of the Gypsum Industry of the State of Pernambuco (Sindusgesso) reinforced the need for determining a more appropriate energy matrix in calcination kilns and implementing environmental projects for regional sustainability (SEBRAE-PE, 2020). According to Sindusgesso (2014), the industries have an energy demand of 54,390 m^3 of firewood per month.

Alternatives to meet this demand have already been presented, including the sustainable forest planning of Caatinga. However, considering that the average production of exploited areas under management is 46.5 m^3 ha-1, after 15 years of rotation, it is necessary to exploit 14,036 ha per year-1 with plans for sustainable vegetation management to meet the demand for firewood fuel of the Araripe industrial park. It implies a total area of 219,541.94 ha of native vegetation under the management regime (SINDUSGESSO, 2014). Thus, the pressure on the native forest is very high, inducing the process of deforestation and desertification of areas, since the edaphic and climatic conditions do not favor a rapid regeneration of vegetation (CAMPELLO, 2013) and cannot meet the demand of the plaster companies (GRANJA et al., 2017).

However, when analyzing the food security of farmers in the Plaster Pole, the main crops grown in the region are beans (*Phaseolus vulgaris* L. and *Vigna unguiculata* L.), cassava (*Manihot esculenta* Crantz), and maize (*Zea mays* L). These three crops account for more than 90% of all agricultural production in the region of the Araripe Plaster Pole (IBGE, 2021), with the municipality of Exu being the largest producer of beans and maize, where Araripina is responsible for the largest production of cassava (Table 1).

Table 1. Main agricultural crops of the municipalities of the Araripe Region.

Municipality	Beans				Cassava				Corn			
	Planted area (ha)	Production (ton)	Average yield (kg/ha)	R$ (Thousand)	Planted area (ha)	Production (ton)	Average yield (kg/ha)	R$ (Thousand)	Planted area (ha)	Production (ton)	Average yield (kg/ha)	R$ (Thousand)
Araripina (PE)	6.000	756	180	1.512	11.000	98.000	8.909	15.680	10.000	630	180	523
Bodocó (PE)	2.500	500	250	1.500	3.100	24.800	11.810	3.546	5.000	660	300	330
Cedro (PE)	400	130	1.111	325	-	-	-	-	1.150	438	1.485	913
Dormentes (PE)	3.000	96	160	255	-	-	-	-	4.500	36	80	24
Exu (PE)	6.000	2.400	400	4.800	3.600	41.600	11.556	6.656	7.500	4.440	600	3.129
Granite (PE)	200	28	280	84	-	-	-	-	600	75	300	53
Ipubi (PE)	5.000	480	200	1.440	3.700	21.500	7.167	6.450	6.500	1.120	400	963
Ouricuri (PE)	8.000	288	180	893	250	1.625	6.500	231	12.000	360	180	310
Parnamirim (PE)	1.200	29	242	78	-	-	-	-	1.200	18	300	15
Santa Cruz (PE)	3.000	252	180	504	-	-	-	-	4.000	96	120	55
Santa Filomena (PE)	3.500	72	60	180	3.000	6.250	2.500	944	5.000	120	60	76
Serrita (PE)	1.200	29	121	81	-	-	-	-	1.600	13	102	10
Moreilândia (PE)	640	12	98	30	100	860	8.600	172	800	130	542	111
Terra Nova (PE)	300	4	133	11	-	-	-	-	300	5	333	4
Trindade (PE)	1.600	60	125	177	100	250	5.000	41	1.200	48	400	41
Total	42.540	5.136	3.720	11.870	24.850	194.885	62.042	33.720	61.350	8.189	5.382	6.557

Source: IBGE, 2021.

Impacts of climate change on Araripe Plaster pole

Global projections indicate that the demand for freshwater, energy, and food increases significantly in the coming decades under pressure from factors such as population growth, economic development, and climate change. Therefore, technologies that promote sustainable development and food security using clean energy and water efficiency while guaranteeing the production of basic foodstuffs are imperative for the Araripe Plaster Pole. According to the Brazilian Panel on Climate Change (PBMC), the climate scenarios for the semi-arid region point to an increase in the average temperature of up to 4.5 °C and a decrease in the distribution of rainfall by up to 50%, considering the last decades of this century, thus inducing an increase in the occurrence of extreme events, such as droughts and prolonged droughts (AMBRIZZI; ARAÚJO, 2013). Regionalized scenarios confirm the trends of increasing air temperature for the municipality of Araripina (LACERDA et al., 2016).

As noted, beans, cassava, and corn are the main crops grown in the region of the Araripe Plaster Pole, with great importance for food and economic security (Table 1). They have socio-economic importance, especially for small producers, and are used for human and animal food. Moreover, they represent important sources of raw material for agro-industrialized products (ARAÚJO; ARRUDA JÚNIOR, 2013; EMBRAPA, 2011; SILVA et al., 2016).

Given the direct relationship of climate and agricultural production, impacts on their cultivation may be diagnosed in climatic scenarios. The increase in temperature can prolong the growing cycle of some cowpea cultivars, apart from promoting a significant increase in the percentage of aborted flowers, reducing the final production of the crop (ANGE-LOTTI et al., 2020; BARROS et al., 2021a). Beyond temperature, changes in rainfall patterns can negatively affect the production of this grain (BARROS et al., 2021b).

For maize, night temperatures above 24 °C increase the respiration rate, reducing photo-assimilates and causing a fall in production (SANS et al., 2001). Regarding water deficit, like cowpea, maize is also sensitive to stress during the reproductive phase of the crop, preventing it from reaching its growth and production potential (BERGAMASCHI; MATZENAUER, 2014).

The cassava, in turn, is a species adapted to tropical climate regions and can be grown in places with a temperature range between 18 °C and 35 °C (JARVIS et al., 2012; NWAIWU et al., 2014). However, the range between 25 °C and 27°C is considered optimal for plant vegetative activities (JARVIS et al., 2012; NWAIWU et al., 2014). For this crop, prolonged water deficit leads the cassava plant into a dormant or resting period (ALVES, 2006), and temperatures above

37 °C paralyze bud sprouting in the manioc (GABRIEL et al., 2014), resulting in reduced production.

Thus, the real problem faced by producers/agriculturalists in the region of the Araripe Plaster Pole is the current energy fragility (energy matrix) and food fragility (traditional crops), aggravated by climate change scenarios.

Adaptation measures for sustainable agriculture in Araripe Plaster Pole

The family farmer of the Plaster Pole must produce food on his rural property, whether food crops or animal husbandry, especially sheep and goats, to ensure their food security. Moreover, he uses firewood from the Caatinga to serve the plaster industry and as a primary energy source for burning (JALIL et al., 2017; BARROS JÚNIOR et al., 2018; GIODA, 2019).

Given this problem, intercropping models emerge as an alternative to ensure energy and food security in the region. In this context, cropping systems include economic efficiency, resources, and improved livelihoods to develop the Araripe region.

We highlight some important initial steps, such as the *screening of* cultivars tolerant to the increase in temperature and water deficit to indicate intercrops. The use of tolerant materials enables an increase in the adaptive capacity and resilience of crops, ensuring sustainable development and food security. Based on the diagnosis of tolerant cultivars, the proposed crops should be based on intercropping (human and animal) food and energy crops. Hence, to address the energy aspect, the alternative would be to invest efforts in the use of crops that show resilience and high productivity and can be used by the plaster industry, as in sorghum biomass (*Sorghum bicolor (*L.) Moench). Accordingly, it is expected to offer options that ensure food, energy, and water security (Figure 2) for the region, given that such crops should not be selected based on their adaptive characteristics to the semi-arid region. To ensure water security, besides genotypes with tolerance to water deficit, management alternatives that promote efficient water use and rainwater capture and storage must be implemented (RIBEIRO; OLIVEIRA, 2019). Other technologies, such as using nitrogen-fixing bacteria, mulching, and agroforestry systems, can integrate the cropping systems (Figure 2).

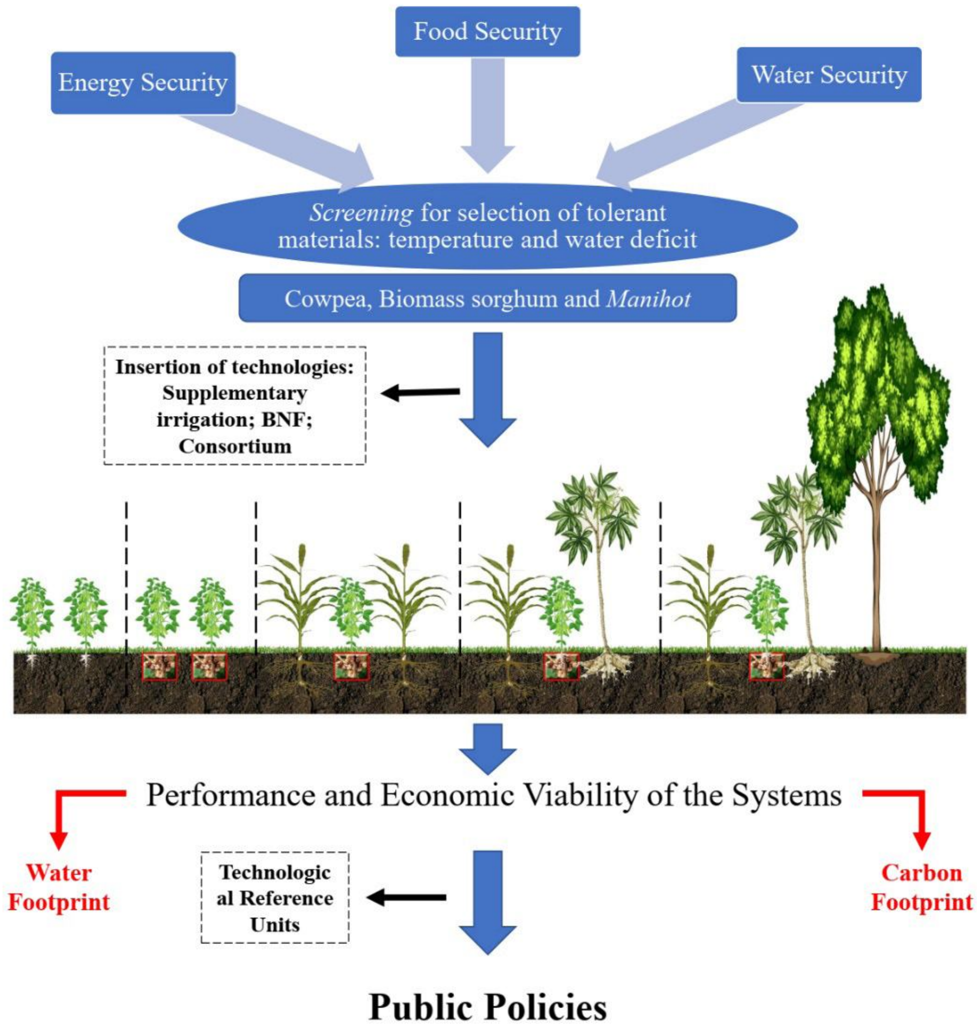

Figure 2. Strategies for sustainable development of agriculture in the Araripe Plaster Pole, Brazil.

Implementing monocultures is characterized by oversimplifying the cultivation system, compromising the natural renewal and maintenance of soil fertility. Thus, external means are sought to replace nutrients to crops through artificial fertilizers, almost always from non-renewable sources. This leads to a reduction in the resilience or plasticity of the system, comprising the capacity of organisms to address climatic adversity, adapt to change, or resist the pressure of adverse situations, thereby reducing their stability to variations in environmental factors.

It then increases vulnerability given ecological imbalances and the need for external intervention for adequate production levels. All factors compromise the production system's sustainability.

Thus, to achieve sustainability, the proposal of agroecosystems is based on the limited use of energy and external resources to re-establish the food chains and keep biogeochemical cycles closed as much as possible, hence inducing interest in integrated systems through intercropping. Adopting intercropping minimizes the fragility of traditional production systems and the effect of total removal of areas in the region, increasing resilience. Using agroforestry systems, where the biomass from periodic pruning can be incorporated into the soil, transfers nutrients from the trees to annual crops (NAIR, 1993), reducing competition for light, water, and nutrients within the system (MARTINS et al., 2013). The interactions of soil, animal, and plant species in all directions and different magnitudes are notable in the agroecosystems, representing the potential for economic and environmental benefits for producers and society. They are multifunctional systems with the possibility of intensifying production through the integrated management of natural resources, avoiding degradation, and promoting the recovery of productive capacity (SILVA, 2004) beyond being a measure of mitigation and adaptation to climate change impacts, hence attributing greater resilience to food, energy, and water security. Thus, developing multifunctional agroecosystems is a highly viable option for the Araripe region. Within these systems, selecting traditional food crops of the semi-arid region, such as cowpea and cassava, has fundamental importance given their socio-economic value for the Northeast, mainly because they constitute a basic food component of the populations and are sources of protein and carbohydrates, rich in minerals and fibers (FUKUDA, 2001; FREIRE et al., 2011). Further, cowpea and cassava can be used as forage, hay, silage, flour for animal feed, and green manure and for soil protection. According to Freire Filho et al. (2011), cowpea has a short cycle and low water requirements and rusticity. It also fixes nitrogen through bacteria symbiosis, which gives it the advantage of developing in low fertility soils. In tropical environments, such as the semi-arid region, biological nitrogen fixation (BNF) is vital because soils have low fertility, and nitrogen availability is poor given nutrient losses in the soil-plant system (MARINHO et al., 2014). Thus, cassava is extensively used by humans for its important social role as a source of carbohydrates, wide adaptation to different ecological conditions, and productive potential.

Alternatively, one can opt for intercropping with maniçoba (*Manihot pseudoglaziovii* Pax & K. Hoffm). Maniçoba is a native species of the Caatinga, ecologically adapted to the semi-arid region and with drought-tolerant characteristics.

The cultivation of native species of the Caatinga is an important alternative to increase the supply of forage, valuing the regional biodiversity. These plants stand out as forage, given their high degree of palatability. Further, maniçoba has a good protein content and digestibility (SANTANA et al., 2008), meeting the dietary needs of livestock. As an option for intercropping, biomass sorghum is a viable alternative for expanding energy sources for farmers in the Araripe region, as it produces high-quality biomass. Moreover, sorghum has an efficient photosynthetic process, similar or even superior to that of sugarcane (Saccharum officinarum) and elephant grass (Pennisetum purpureum Schum.). The ability to adapt to tropical and temperate climates, its high water use efficiency, its tolerance to drought, and its potential capacity to produce large quantities of lignocellulosic biomass are some of the numerous strengths of this species (PARRELLA, 2013). Biomass sorghum is a more promising technology than grass and even eucalyptus, given that the species can reach yields of 150 t ha-1 of fresh mass (50 t ha-1 of dry matter) in a cycle of only five months. Additionally, biomass sorghum can be propagated via seeds, generating a lower operational cost.

Another positive aspect of biomass sorghum is the chemical characteristics of the raw material, desirable in combustion processes in calorific value, fixed and volatile carbon content, ash content, and alkali metal content. As deforestation has intensified in recent years in the Araripe region, an energy alternative can positively impact the sustainability of the region, generating income for family farmers and avoiding deforestation. Notably, sorghum biomass is another energy component that primarily reduces the use of firewood from Caatinga because the sorghum dry matter has a lower density than firewood, addressed using densified products such as briquettes and *pellets* (SIMEONE et al., 2018).

Research on biomass sorghum began in the states of Minas Gerais and São Paulo, given the location of Embrapa Maize and Sorghum. However, research on using this grass as a primary energy source has garnered the attention of producers in Mato Grosso and other states in the Midwest and Southeast. The possibility of its adoption in the semi-arid region, notably in the Araripe region, is significant when considering conservation issues in the Caatinga Biome.

Another alternative would be BNF, where bacteria fix atmospheric nitrogen into organic compounds used by plants, reducing the need for nitrogen fertilizers and improving the uptake of water and nutrients. Thus, this technique allows for greater plant production and an increase in the ability to withstand environmental stresses, which can be an additional tool in integrating family farming technologies, increasing the productive potential of agricultural activity. Prior studies indicate the potential use of this association for legumes (SUAREZ et al., 2008; NEUMANN; GEORGE, 2009). For cowpea, four *Bradyrhizobium* sp. strains are currently authorized to produce inoculants in Brazil (BRASIL, 2011), the most widespread being strain BR 3267, originating from soils of Petrolina (MARTINS et al., 2003), thus demonstrating the potential of the region as a source of efficient microorganisms. Furthermore, the plant genotypes cultivated in the semi-arid region show variable responsiveness to the inoculation of bacteria used in commercial inoculants (MARI-NHO et al., 2014), reinforcing the need for constant prospecting of new rhizobium isolates. Thus, selecting new isolates of rhizobia for cowpea is an important objective cultivated under conditions of environmental stress and may be an important initiative to obtain new bacteria for this crop, given that studies to select new bacteria in the Brazilian semi-arid region remain scarce, and data on bacterial selection from combined conditions of high temperature and water deficit are non-existent.

Table 2 presents the systematized information about the main impacts of climate change in the Araripe region. Notably, given this diagnosis, adaptation measures can be adopted to reduce the negative effects foreseen in future scenarios (Table 2). Assertive public choices should be sought to promote sustainable development effectively. Thus, the proposition of public policies that support the adoption of adaptation measures should be developed per the local reality, allowing for the exploitation of economic opportunities and social (ROMERO; ZUGMAN, 2010). Implementing viable measures, economically and managerially, is of paramount importance, given that producers must be willing to adopt them for their effective use (MAGALHÃES, 2017).

Table 2. Options for adaptation measures in the face of impacts caused by climate change.

	Impacts	**Adaptation measures**	**References**
Increase in air temperature	Crop cycle extension; Increase in flower abortion; Paralyzes bud sprouting; deviation of photo-assimilates; seriously compromising the grain yield; Increases the severity of water deficit; Loss of biodiversity; reduction in agricultural production	Selection of tolerant cultivars; Change of planting time; No-tillage system in straw; Use of plant cocktail; Polyculture; Conservation and use of genetic resources of cultivated and native species; Crop integration; Public policies	ANGELOTTI et al. 2012; GIONGO, 2019; BARROS et al., 2021a ; PAUL et al., 2017 MAGALHÃES, 2017 SANS et al., 2001
Changes in precipitation patterns	Reduced stomatal aperture; drop in photosynthesis; Increased leaf temperature, thus affecting respiration; Drop in production; Reduced growth and dry matter	Rainwater harvesting technologies (cisterns, underground dams); Biological nitrogen fixation; Growth-promoting rhizobacteria in plants public policy	CESANO et al., 2012; BRITO et al., 2012; MARINHO et al., 2014
Energy Matrix	Deforestation; Desertification; Loss of biodiversity	Alternative energy sources for burning; Energy forests; Public policies	PARRELA, 2013; OLIVEIRA et al., 2018

The adaptation measures stem from the observation that production systems for family farmers should be much more structured and complex, seeking the integration of technologies to meet food, water, and energy demands, where the survival of farmers and quality of life are considered. However, all actions should be based on sustainable systems and conserving and preserving the Caatinga Biome. Actions of this type are guided via multidisciplinarity to visualize the necessary transversality in complex systems such that the whole is considered when proposing an intervention or productive system model to the producer. Thus, it is simultaneously a great opportunity and a challenge, being fundamental to consolidate the structuring of production units and promote sustainable development for family farming in the Araripe Plaster Pole.

Final considerations

The socio-economic role of gypsum in the communities living in the semi-arid Araripe region will be maintained in the coming decades. Efforts should be intensified to improve the energy performance of the gypsum production chain and develop simple and cost-effective options to promote the sustainability of a diverse farming base. Desertification, drought, and global warming justify the need for serious reflection on establishing new strategies for gypsum production and agriculture to improve food production and income generation without detrimental environmental effects. Therefore, the region's development objectives should move toward conservation and sustainable management of natural resources while concentrating efforts to optimize gypsum production and agricultural products sustainably, including livestock. However, strategies should also be designed for the broad transfer and adoption of options to entities such as local communities, farmers' associations, and NGOs. Equipping policymakers with technical data and forward-looking scenarios is also a strategy to boost the region's sustainable development.

The projection of multifunctional agroecosystems should be the focus of the proposal of resilient systems incorporating technologies developed over the years, with emphasis on selecting plant species tolerant to salt, water, and thermal stress, the use of rhizobial inoculants for the economic and environmental benefit of legumes and intercropped crops, adopting no-tillage farming systems, planting native tree species and technologies for collection, and storage and use of rainfall with high efficiency and productivity.

The models of functional, sustainable, intensive agroecosystems use increasing levels of complexity in the inter- and intra-relationships of their multiple components as strategies to increase resilience and water, food, and energy security. Thus, implementing cropping systems that integrate food and energy crops using water-efficient materials can be the basis for formulating public policies that contribute to the diffusion and incorporation of such strategies in other regions, communities, and governmental organizations. The cropping system proposals support energy and nutritional security policies to address climate change, strengthening sustainable agriculture.

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