



Sustainable agriculture in warm semiarid lands

Agricultura sustentável em terras semiáridas quentes

Agricultura sostenible en tierras semiáridas cálidas

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ABSTRACT: The objective of this essay was to carry out a synthesis of sustainable agriculture in the state of Ceará, Semiarid Region of Brazil, from the perspective of agroecology. It is the result of a collaborative effort between rural development organizations and teaching and research institutions and is based on the results of debates and research, teaching materials and the bibliography. Due to climate severity and uncertain socioeconomic and political conditions, agriculture in the semiarid region of Brazil is characterized by the low use of financial resources, rainfed agriculture and extensive livestock farming. About 70% of the producers are family farmers, who grow corn and beans in small areas, without technical assistance, most of them practicing subsistence agriculture. Extensive livestock farming is based on grazing native vegetation and there are often degraded pastures. The following analysis suggests that sustainable agriculture in Ceará goes through a process of building agroecological knowledge and awareness, based on practices and debates on how to coexist with the semiarid condition. The use of adapted plant and animal species, soil and water conservation, the local preservation and increase of agrobiodiversity and integration between agricultural, processing and commercialization activities have been pointed out as strategies to improve agriculture sustainability in the region. Thus, apparently, there is a shift towards a socio-environmental rationality for sustainability, as opposed to the notion of fighting drought. These changes in basis take place amid contradictory proposals

from the federal and state governments which are allied with and benefit agribusiness with large volumes of public investment, on the one hand, and allocate modest resources to sustainable agriculture on the other.

Keywords: agroecology; agroecosystem evolution; Brazilian semiarid region; family farming; rural development.

RESUMO: O objetivo deste ensaio foi fazer uma síntese da agricultura sustentável no estado do Ceará, Semiárido do Brasil, a partir da agroecologia. É o resultado de um esforço colaborativo entre organizações de desenvolvimento rural e instituições de ensino e pesquisa e baseia-se em resultados de debates e pesquisas, materiais didáticos e bibliografia. Devido ao clima severo e condições socioeconômicas e políticas incertas, a agricultura no semiárido brasileiro é caracterizada pelo baixo uso de recursos financeiros, agricultura de sequeiro e pecuária extensiva. Cerca de 70% dos produtores são agricultores familiares, que produzem milho e feijão em pequenas áreas, sem assistência técnica, a maioria praticando agricultura de subsistência. A pecuária extensiva baseia-se no pastoreio de vegetação nativa e pastagens degradadas são frequentes. A análise realizada sugere que a agricultura sustentável no Ceará passa por um processo de construção de conhecimento e consciência agroecológica, a partir de práticas e debates sobre a convivência com o semiárido. A utilização de espécies animais e vegetais adaptadas, a conservação dos solos e das águas, a conservação local e o aumento da agrobiodiversidade e a integração entre as atividades agrícolas, processamento e comercialização têm sido apontadas como estratégias para melhorar a sustentabilidade da agricultura na região. Assim, aparentemente, está ocorrendo uma mudança para uma racionalidade socioambiental da sustentabilidade, oposta à noção de combate à seca. Essas mudanças de base estão ocorrendo em meio a proposições conflitantes dos governos federal e estadual que se associam e beneficiam o agronegócio com grandes volumes de investimento público, por um lado, e destinam recursos modestos à agricultura sustentável, por outro.

Palavras-chave: agricultura familiar; agroecologia; desenvolvimento rural; evolução de agroecossistemas; semiárido brasileiro.

RESUMEN: El objetivo de este ensayo fue realizar una síntesis de la agricultura sostenible en el estado de Ceará, Región Semiárida de Brasil, desde la agroecología. Resulta de un esfuerzo colaborativo entre organizaciones del desarrollo rural e instituciones de enseñanza e investigación y toma por base resultados de debate y de investigación, materiales de enseñanza y la bibliografía. Debido a la severidad del clima y las inciertas condiciones socioeconómicas y políticas, la agricultura en la región semiárida de Brasil se caracteriza por un bajo uso de recursos financieros, agricultura de secano y producción ganadera extensiva. Alrededor del 70% de los productores son agricultores familiares, que producen maíz y frijoles en áreas pequeñas, sin asistencia técnica, la mayoría de ellos practicando la agricultura de subsistencia. La ganadería extensiva se basa en el pastoreo de vegetación nativa y los pastos degradados son frecuentes. El análisis realizado sugiere que la agricultura sostenible en Ceará pasa por un proceso de construcción de conocimiento y conciencia agroecológica, a partir de las prácticas y del debate sobre la convivencia con las condiciones de semiaridez. El uso de especies animales y vegetales adaptadas, la conservación de suelos y aguas, la conservación local y el aumento de la agrobiodiversidad y la integración entre las actividades agrícolas, el procesamiento y la comercialización han sido señaladas como estrategias para mejorar la sostenibilidad de la agricultura en la región. Así, aparentemente, se está produciendo un cambio hacia una racionalidad socioambiental de la sostenibilidad, opuesta a la noción de combate a la sequía. Esos cambios, impulsados por las bases, tienen lugar en medio a proposiciones contradictorias de los gobiernos federal y estadual que se alían y benefician al agronegocio con grandes volúmenes de inversión pública, por un lado, y destinan modestos recursos a la agricultura sostenible, por otro.

Palabras clave: agricultura familiar; agroecología; desarrollo rural; evolución de agroecossistemas; semiárido brasileño.

1. Introduction

Agriculture is in permanent evolution, stimulated and/or pressured by social processes of change, such as the emerging demands and actions of producers and consumers, concerned with production costs and the quality of the final product; the sovereignty and food and nutritional security of the territories; as well as the socio-environmental impact of contemporary modes of production and the expectation of a common future.

Agroecology emerged in the 1970s with the aim of studying the problems of ecological and social sustainability of production (Sevilla Guzmán & Alonso Mielgo, 1994), in response to the various crises generated by the modernization and intensification of agriculture, based on the spread and expansion of the Green Revolution. It is also a form of resistance to centralized, diffusionist, conservative and exclusionary rural development policies, projects and actions that demand a differentiated approach, starting with the farmer and ending with him (Hecht, 1987).

In the complex field of agrifood systems, although initially focused on agricultural issues, agroecology develops in interaction with rural and environmental social movements and from different disciplines, such as agrarian, ecology, geography, history, anthropology, sociology, solidarity economy and ecological economics. Thus, more than a specific discipline, agroecology is understood as science, movement and practice (Wezel *et al.*, 2009).

As a result, the perception of agroecology is dynamic. Altieri (1999) emphasized the importance of agroecology as a discipline that provides ecologi-

cal principles for the study, design and management of productive agroecosystems that conserve natural resources, as well as being culturally sensitive, socially just and economically viable. For Caporal & Costabeber (2002), agroecology corresponds to the field of knowledge that provides the scientific basis for sustaining the process of transition from the conventional agricultural model to ecologically based or sustainable agricultural styles. Sevilla Guzmán (2006) defines it as the ecological management of natural resources, through forms of collective social action that present alternatives to the current crisis of Modernity, by means of participatory development proposals from the spheres of production and alternative circulation of its products, with the intention of establishing forms of production and consumption that contribute to face the ecological and social crisis and, in this way, reestablish the altered course of social and ecological co-evolution.

As a field of knowledge that brings together agricultural and rural social practices and experiences, theoretical reflections and scientific advances from different disciplines, agroecology questions the assumptions and forms of knowledge production of Cartesian analytical science and proposes a systemic, inter- and transdisciplinary approach, seeking to address the complexity of social and environmental systems in a dynamic and participatory perspective. The premises of complexity, the systemic approach and the cognitive-constructivist approach leave no doubt about the need for methodological and epistemological pluralism. In this sense, it is possible to speak of a vanguard proposal for the production of knowledge in analytical, positivist and atomistic science that has been institutionalized

in education, research and agricultural and agrarian public policies (Gamarrá-Rojas, 2019).

In Brazil, agroecology permeates the spheres of practice, management, teaching, research and policy as a collective action of knowledge construction, capacity building and creation of adaptive strategies, guided by the notion of sustainability in its broad and constructivist sense, with different conceptual and methodological contributions.

In this context, a qualitative essay is presented (Prodanov & Freitas, 2013) resulting from the collaboration between local rural development organizations and teaching and research institutions, gathered in the Nucleus of Studies in Agroecology and Ecological Economics of Ceará - NEAEE¹. It aims to provide an updated synthesis of sustainable agriculture in the Semiarid Region of Ceará, Brazil, with an agroecological approach, and seeks to establish a dialogue with related initiatives, particularly in Latin America.

It is based on a preliminary opinion article, requested to the referred NEAEE by the Brazilian Society of Soil Science (Gamarrá-Rojas, 2020); the outputs of debates and research in the form of Degree and Master's Theses, such as: Moraes Mora (2018), Pinheiro *et al.* (2023) and Dobe *et al.*, (2020); previous university teaching texts for the Agricultural Sciences Courses of the Federal University of Ceará elaborated by the authors and the pertinent bibliography.

The introductory text presents the conceptual and epistemological bases that guide the document.

It then briefly illustrates the natural setting of the semiarid region of northeastern Brazil. It follows with an outline of the historical and evolutionary formation of agriculture and a characterization of the farmers and agroecosystems of the Brazilian semiarid region. It then explains the relationships between family farming, the semiarid condition and agroecology, and then develops the themes that are the object of reflection and research in the context of the NEAEE. Among these, the role of rural women and youth; marketing and markets for organic and agroecological products; agroecosystem studies; fertility renewal; management of agrobiodiversity and native seeds; rural extension and sustainable agriculture policies; and finally, an analytical synthesis with a prospect for research action and participation.

2. The semiarid environment

Ceará is one of the nine states of the Northeastern Region of Brazil (Figure 1) characterized by the predominance of the Caatinga biome. This biome, exclusively Brazilian, has a semiarid, warm and seasonal climate (BSh type, according to the Köppen classification), with less than 1,000 mm of annual rainfall, distributed between three to six months. Potential evapotranspiration is high, between 1,500 and 2,000 mm per year. Rainfall totals vary widely and, at intervals of about ten years, fall

¹ Project 403049 / 2017-2, Call for Proposals MCTIC / MAPA / MEC / SEAD - Casa Civil / CNPq No. 21/2016, carried out in cooperation between Caritas (Ceará Regional Brazilian Caritas), Cetra (Studies Center for Work and Advice to Workers), Embrapa Agroindústria Tropical and UFC (Federal University of Ceará).

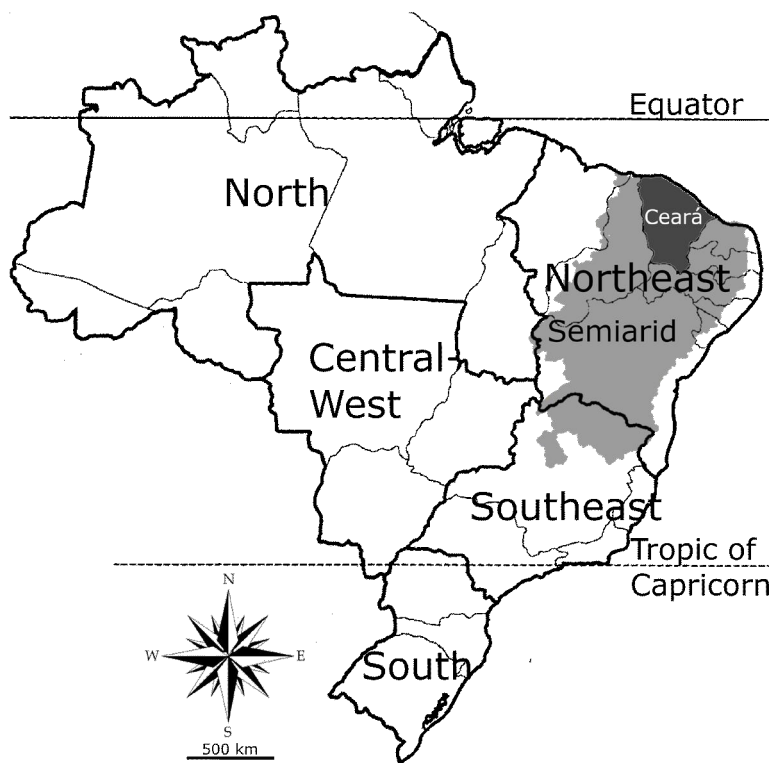


FIGURE 1 - Large regions of Brazil, location of the semiarid region and the state of Ceará.
SOURCE: adapted from IBGE

to less than half the average for three to five years in a row, causing "drought" (Velloso *et al.*, 2002).

Despite the severe conditions, the Caatinga biome presents a great diversity of ecological environments, exhibiting a mosaic of vegetation types, generally deciduous, xerophytic and sometimes thorny, which vary according to soil diversity and water availability. Caatinga² is the predominant vegetation in the semiarid region and is characterized by vegetation ranging from shrubby savannas to dry forests, rocky outcrops dominated by cacti and

bromeliads, to enclaves of sub-humid high altitude forests (Velloso *et al.*, 2002).

Ceará is inhabited by 9,075,649 people, distributed over an area of 148,920.472 km², of which approximately 98% are in a semiarid climate (IBGE, 2017).

3. Agricultural development in the semiarid region

In the Brazilian semiarid northeastern states, agriculture dates back to the period of endosoma-

² Tupi-Guarani name (*caa*: forest and *tinga*: white) meaning "white forest".

tic³ consumption by native peoples who associated hunting, fishing and gathering of vegetable products with the cultivation of native and/or adapted food plants. The native peoples had a food 'criterion' that was neither improvised nor lacking. The food tradition for these peoples was synonymous with the food that guaranteed physical preservation, whereas the other foods went to the class of complements that provided satiety (Cascudo, 2011). Although the information on the food tradition for the semiarid region is fragmented⁴, it can be said that, among the former, game meats such as deer (*Mazama* spp.), caititu (*Pecari* sp.), armadillo (*Euphractus* sp.; *Tolypeutes* sp.), rodents such as agouti (*Dasyprocta* spp.), mocó, also known as rock cavy (*Kerodon* sp.) and preá (*Galea* sp.). Among the vegetables, the food complexes of cassava (*Manihot* spp.) and corn (*Zea mays*) are the most widespread, as well as sweet potato (*Ipomea* sp.), beans (*Phaseolus* spp. and *Vigna* spp.) and peanuts (*Arachis* spp.). Among the latter, palm trees stand out for their wide repertoire in material culture, providing foods such as palm heart and the pulp and seeds of the fruits of carnaúba (*Copernicia prunifera*), macaúba (*Acrocomia* spp.) and ouricuri (*Siagrus* spp.); the fruits of the complex of species of the genus *Spondias*, such as umbú and cajá, the species of cashew (*Anacardium* spp.), pineapple (*Ananas* spp.), ata (*Annona* spp.), murici (*Byrsonima* spp.), pitanga (*Eugenia* spp.), jatobá (*Hymenaea* spp.), passion fruit (*Passiflora* spp.), pequi (*Caryocar* sp.) and

the cumbeba cactus (*Tacinga inamoena*), as well as ants, insect larvae and fish.

The semiarid condition led human populations in the region to concentrate in lands near the valleys or lowlands, because of the greater availability of water for productive activities, particularly ebb and flow agriculture (Antonino & Audry, 2001).

Subsequently, the Iberian colonization introduced plant and animal agrobiodiversity of European, African and Asian origin, diversifying the food pattern and rural economic options. Simultaneously, the productive relations of the time were instituted, with the subjugation - and extinction - of indigenous peoples and slavery. Thus, between the 16th and 18th centuries, the sugar agro-export model was consolidated, consisting of sugarcane plantations distributed along the humid Atlantic coast of the Northeast; supply agriculture, practiced on the periphery of the sugarcane fields, which included the raising of draft animals (cattle, horses and asinine) for the transport of goods to the port and, later, extensive cattle ranching was introduced on the frontier of the semiarid region (Linhares, 1995).

In the semiarid, extensive cattle ranching was carried out with rustic cattle and the Caatinga served as pasture (Barroso, 1962). Meanwhile, the basic subsistence of the cowboys and farmers was provided by indigenous-based agriculture (Veirano, 1962). The practices of this semi-itinerant 'traditional' agriculture, called slash and burn, consisted of deforestation, burning of plant material, cultivation

³ Endosomatic refers to the energy needed to meet the biological demands of human beings. The term is used in Agroecology and Ecological Economics to contrast with the exosomatic consumption of energy, typical of modernity, where energy consumption comes to privilege the satisfaction of 'cultural needs' of mass consumption societies.

⁴ Information on the species used as food by the native peoples of the semiarid is presented from indirect evidence: Braga (1960), Giacometti (1993), Queiroz *et al.* (1993), Cruz *et al.* (2002), Gamarra-Rojas & Gamarra-Rojas (2002), Sampaio & Gamarra-Rojas (2002), Gamarra-Rojas *et al.* (2004) and Cascudo (2011).

and/or maintenance of several species in the same area and manual weeding for two to three years. The land, eventually enriched with perennial species, is then left to rest for forest regeneration or eventual future use. This system, widely spread in the forest regions of the planet, gave way to permanent systems of land use, conditioned by the increase in population density and the decrease in resting time (Mazoyer & Roudart, 2010); then by the regime of private land ownership, consolidated, in the case of Brazil, in the Land Law in the nineteenth century⁵.

In the Brazilian territory, the legal instrument of land tenure until the 19th century was the *Sesmaria*, which consisted of public deeds of donation of land by the Portuguese government with the intention of promoting agriculture and cattle raising and those who exploited it were large landowners who had the right of use granted by the crown. The so-called poor and free men lived on other people's lands, generally granted by the powerful of the area, who, for the right of usufruct, collected from this population parts of the harvest, rent, labor or political favors. It should be added that these forms of access to land coincided with the historical period of slavery, before land was considered a commodity (Wanderley, 2009).

Since the middle of the 18th century, Ceará's economy has been based on cattle raising and industrialization of salted and dehydrated meat

(charque) to serve internal and external markets, with moments of crisis caused by periods of drought and also by competition in the market imposed by the state of Rio Grande do Sul, which began to dominate the supply of charque.

The cattle raising activity was carried out through the open field system and extensive cattle raising, which configured its own income generation mechanism, based on the work of the cowboy and the monopsony, which is a form of market with a single buyer, practiced by the landowners themselves (Cerqueira, 1988). Thus, the income was transferred from the cowboy to the *sesmeiro* and, eventually, to an intermediary. The farmers, who practiced agriculture and small animal husbandry, had a conditional guarantee of occupation and permanence on the farm, transferring part of the income to the *sesmeiro*, either by rent or by participation in production. In this context, the expansion of cattle raising towards the frontier of the semiarid translated into an economic, practical and political determination, ensuring the occupation of the territory by the Portuguese crown, while remaining a link in the pattern of accumulation in force at the time (Linhares, 1995).

Subsequently, and despite the crises that periodically affected the agro-industrial export sector, such as the abolition of slavery and the consequent transition to the wage regime (Furtado, 1964), even

⁵ The Land Law (Law No. 601 of September 18, 1850) was enacted shortly before the abolition of slavery and established the conditions under which land could be appropriated by private agents, who were required to register it. The incorporation of State lands, which had not been incorporated by means of the extinct *Sesmarias* or recognized possessions, would take place through purchase and sale processes. Since the independence of Brazil in 1822, until the approval of the Land Law, there were attempts to approve projects that sought to inhibit the concentration of land, foreseeing the requirement of registration, collection of land tax; conditioning the property to the cultivation of the land. Still, the tax clause was suppressed and the limit of ownership was extended to the size of the largest *Sesmaria* existing in the district, and the determination of land registration was not operated until the end of the 19th century. That is, the Land Law maintained and crystallized the power of the large landowners, in addition to establishing that, from 1850 onwards, the only way to access land that had not yet been appropriated would be by purchase. This eliminated any threat of the slave population gaining access to land from the abolitionist process, which in Brazil occurred only in 1888 (Almeida, 2015).

in the 1960s these patterns did not change. Veirano (1962) showed as an agrarian characteristic of the Northeast the scarce change in the modalities of land use. The way in which the agrarian space was structured and the social relations that prevailed in it, meant the possession of power and the capacity to enforce the interests of the landowners, through the political prestige they had and by the use of the state machinery in their favor, which configured a social relationship of command-servitude and became a cultural mark of the northeastern rural society (Andrade, 1997).

Side by side, or integrating with the traditionally established agroecosystem - extensive cattle raising and polyculture for food production - two other economic modalities occurred: plant extractivism and industrial crops such as cotton, agave and castor beans. Of the latter in Ceará, cotton cultivation, associated with a short-lived textile industry, stands out as the second economic activity in the semiarid, from the 18th to the 20th century (Duque, 1980).

Mocó cotton (*Gossypium* spp.), a semi-evergreen fibrous shrub native to the semiarid, was inserted into the food-producing agroecosystem, in temporal and spatial combinations with maize and beans, linked and subordinated to the livestock subsystem (Silva, 1962). After the harvest, the crop areas were opened to cattle to take advantage of crop residues and spontaneous vegetation (Veirano, 1962). The alternation of cultivation areas was practiced as the cotton trees aged, with the consequent maintenance of part of the soil fertility according to the duration of the rest period (Duque, 1980).

Mocó cotton was gradually replaced by herbaceous cotton, with varieties introduced from the United States of America. These areas were domi-

nated by tenant farmers, rural workers and owners of small areas. It was their main source of income, complemented by farm labor in other crops, services and extractivism (Veirano, 1962; Duque, 1980).

The extraction of native plants from the Caa-tinga in Ceará was concentrated on fibrous, oleaginous and wax-producing species, which had their heyday at the time of the Great Wars (Martins, 1962) and were partially substituted by synthetic fibers and waxes derived from petroleum, with the notable exception of the carnauba palm (*Copernicia prunifera*), which maintains its importance, being the tree symbol of Ceará. The production of firewood is a by-product of the opening of areas for shifting agriculture and perpetuates as an independent activity, as firewood and charcoal represent today about 30% of the energy matrix in the Northeast (Riegelhaupt & Pareyn, 2010).

Between 1960 and 1970 the green revolution inspired the search for consolidation of modernization policies in Brazil, with emphasis on agricultural productivity, through monocultures of high-yielding varieties, chemical-synthetic inputs and mechanization. The proposal was sponsored by international cooperation and involved the restructuring of universities and research centers, following a model of innovation based on the production of technology to be disseminated to farmers through rural extension agents. Emphasis was placed on state intervention in infrastructure and subsidies to stimulate private sector investment, a process that has been reproduced to the present day.

These policies have been taken advantage of by productive sectors in an economic position compatible with the recommended technologies, credit arrangements and markets, and have led to a significant increase in exportable agricultural

production with an influence on the country's trade balance. On the other hand, it led to the purchase of oversized equipment and the indebtedness of landowners (Olinger, 1996). It also provided a large market for input oligopolies, mainly pesticides (ABRASCO, 2012).

The Caatinga ecosystems have been significantly altered in their floristic composition, due to the replacement of native species by introduced crops and pastures, increasing grazing pressure causing soil compaction, where water resources, mostly insufficient and intermittent, show compromising levels of contamination (IPECE, 2016).

Nevertheless, the growth of industry and commerce through increased supply and demand for modern technology and products, articulated by the agricultural unit, is considered favorable for the regional economy and remains the central objective of agricultural policies. It would seem to be a modernizing paradigm.

At the time, peasants did not have a policy that was favorable to them either (Andrade, 1997), since the vision of a necessary transformation of traditional/peasant agriculture (Schultz, 1965) predominated, either guided by liberal ideologies or by centralist positions and, consequently, the uncertainty of the destiny and role of peasant agriculture. Since then, industrial agriculture has exerted pressure on traditional and peasant agriculture in the semiarid Ceará, causing adaptations in the agroecosystems, although without becoming a predominant feature.

4. Farmers and agroecosystems in the semiarid zone

In the agricultural landscape of the *cearense* semiarid, it is possible to distinguish at least three types of farmers:

i) family farming⁶, which is based on the work of family members;

ii) traditional livestock farming units and mixed livestock and agricultural operations, where production work is carried out by the family and by permanent or temporary employees; and

iii) agro-industrial units, which include large-scale meat and milk producers and companies benefiting from state irrigation programs based on large dams.

These farmers manage, for the most part, combinations of at least two of the following subsystems: the domestic yard; rainfed and/or irrigated crops; livestock and Caatinga at different stages of ecological succession.

The domestic yards are managed mainly by women and include native and introduced plant species (herbaceous, shrubs and trees) and small animals (poultry, goats and pigs). They reuse domestic wastewater and nutrient flows are intensified between this subsystem and those of extensive farming and annual crops, resulting in high fertility of the yards.

Rainfed annual crops - constitute a type of agriculture totally dependent on rainwater where

⁶ Family farming is a broad term that designates rural family entrepreneurs, foresters, aquaculturists, extractivists, indigenous peoples, rural quilombos and other traditional peoples and communities that present the characteristics defined in Brazil's Family Farming Law, created with the intention of universalizing public policies relevant to this public. In our understanding, it includes peasants. Law 11.326, of July 24, 2006, established the guidelines for the formulation of the National Policy on Family Farming and Rural Family Enterprises, as well as the classification criteria for the adequacy of the family farmer, officially recognizing it as a profession (Brazil, 2006).

the wisdom of the farmer to identify the seasonal dynamics of rainfall is critical (Nasuti *et al.*, 2013). It is the most disseminated mode of agriculture and is characterized by the polyculture of corn, beans, cassava, broad beans, squash, cotton, etc. (Araújo Filho, 2013). In these systems the native biodiversity has been practically eliminated by slash and burn and the area remains bare, with the soil exposed to erosion. The advance of mechanized monocultures, with intensive use of chemical-synthetic inputs, tends to potentiate degradation processes (Araújo Filho & Sampaio, 2004).

Extensive rainfed cattle raising, in general, with two or more species of hardy breeds in the same pasture, is still based on native grasses, in areas with high woody cover or savanna-type Caatinga (Araújo Filho, 2013). Monoculture of forage grasses adapted to the environment is also practiced. However, high external dependence on balanced feed and/or corn persists (Silva *et al.*, 2018) and overgrazing is a constant that results in high erosion, both water and wind, with losses of soil, carbon, nutrients and water, similar to rainfed annual cropping subsystems (Araújo Filho & Sampaio, 2004). The establishment of reserves for periods of drought or to supplement herd feeding with palm (*Opuntia ficus-indica*), cut grass and hay production and silage of sorghum or other annual species is gaining importance among different types of farmers.

Perennial rainfed crops are located in the mountainous and more humid areas (coffee, bananas and other fruits) or in the semiarid (cashew). Management practices are traditional, being associated in the early years with annual crops. Coffee (*Coffea arabica*), mainly of the Typica variety, is grown in agroforestry systems, where biodiversity tends to be higher due to the use of native and exotic plants for shade, biomass, nutrient recycling and nitrogen

fixation. The commercialization of organic coffee has increased among medium and large landowners, although also subject to monopsony, and something similar occurs with organic cashews produced by family farmers (Gamarra-Rojas *et al.*, 2017).

Annual and perennial crops under small-scale irrigation are grown in alluvial areas, backflow areas of small and medium-sized ponds or surface and subway dams of small to medium size that allow the use of water stored in the subsoil and, more recently, rainwater harvesting cisterns (Araújo Filho, 2013). With the remaining or stored water, crops are produced in dry weather, even in periods of drought (Antonino & Audry, 2001). Beans, corn, sweet potato, cassava, pumpkin, vegetables, etc., are grown in combination with fruit trees.

The large irrigated areas come from areas expropriated by the state for the construction of large dams for energy production, urban and industrial water supply, as well as for irrigated agricultural production. The agricultural land in the irrigated perimeters is ceded to settlers and companies through credit activities of the Bank of Northeast Brazil (Banco do Nordeste do Brasil - BNB) and the National Family Agriculture Program (PRONAF). In the settlers' plots, the irrigated area occupies small spaces, with production destined for both the local and regional markets. In the companies, salaried labor and mechanization promote greater exploitation of the area (Sampaio *et al.*, 2004) and production is destined for the local, national and international market. Vegetables, fruits, beans, sugarcane and grass are grown in monocultures or in combinations of up to two crops (Araújo Filho & Sampaio, 2004). The use of chemical-synthetic inputs and the waste of irrigation water are high (Sampaio *et al.*, 2004).

The effect of irrigation programs on regional incomes has served as a justification for the high

government investments in infrastructure and subsidies, which help to sustain this type of agriculture. Simultaneously, there is a gradual socio-economic differentiation of settlers and a tendency to concentrate land in companies, which has led to questioning the socio-technical pattern of these irrigations, considered by social movements and academic sectors as socially discriminatory in their conception and results (Elias, 2002).

Pisciculture and carciniculture are two new farming modalities specialized in a single species. Such monocultures are mainly carried out in dams distributed throughout the semiarid and in coastal areas with mangroves.

Rainfed agroforestry is a more recent modality of agricultural, livestock or mixed intensification, which takes advantage of both well-conserved areas of dense woody Caatinga and intermediate stages of forest succession (Araújo Filho, 2013). Potential combinations are diverse, depending on the purpose, and include annual food and fibrous species, woody species, native fruits and beekeeping (Gamarra-Rojas & Gamarra-Rojas, 2004).

5. Family farming, semiaridity and agroecology

As seen above, family farming in the semiarid region has been facing scarcity, risks and an unfavo-

nable socio-political environment (Gamarra-Rojas & Fabre, 2017). In fact, it was only in the 1990s that its importance for food security and sovereignty was recognized in Brazil. Studies by the National Institute of Colonization and Agrarian Reform (INCRA) and the Food and Agriculture Organization (FAO) showed that family farming is more efficient in the use of land and capital than non-family farming (INCRA; FAO, 2000). However, the distribution of production and income is heterogeneous, both spatially and among groups of family farmers (Bento *et al.*, 2017; Evangelista, 2000).

In Ceará, family farming covers 75% of rural establishments and occupies 51% of the total area exploited by agriculture and livestock (Fortini, 2020), with 78% of this occupying an area smaller than 10 ha or not owning land (IBGE, 2017). These farmers prioritize self-consumption (80%) over commercialization (20%) (Fortini, 2020), but their autonomy to renew their livelihoods is fragile, due to a combination of factors, such as demographic progression and consequent land division that numerically increases smallholdings, environmental degradation - which comes to configure large spaces in the process of desertification⁷ – and the increase of intermediate consumption⁸ in modern agriculture.

Consequently, for the most part, family farming in the semiarid Ceará is decapitalized or decapitalizing, necessarily turning to pluriactivi-

⁷ Desertification is attributed to a process of socio-environmental degradation, either by those who concentrate natural resources, or by those who pressure them in the little or no space available to them (MMA; SRH, 2004). "Several factors contribute to the desertification of the caatinga, highlighting the structure of the land, periodic droughts and the extractive and predatory nature of natural resource exploitation practices... the modernization of agriculture, based on the recommendations of the Green Revolution, has resulted in the acceleration of soil degradation and desertification in some regions of the semiarid" (Araújo Filho, 2013, p. 103).

⁸ Intermediate consumption (IC), understood as inputs acquired from other economic agents and consumed in the production process. The importance of IC in the value of production (PB) can be used as an indicator of self-sufficiency, since the ratio of IC over PB reveals the degree of dependence of farmers on external agents for the acquisition of production factors (Kageyama *et al.*, 1990). In Brazil, the IC went from 10%, at the end of the 1960s, to 40%, due to industrial agriculture (Kageyama *et al.*, 1990). In the Northeast, IC values of 57% were found for non-family farming and 17% for family farming (Conterato *et al.*, 2014) and in Ceará, Bento *et al.* (2017) and Lima and Gamarra-Rojas (2017) found that a higher IC corresponds to lower productive autonomy.

ty⁹, has high dependence on state social programs (Bento *et al.*, 2017) and its capacity for resistance and resilience to recurrent periods of drought is periodically put to the test.

Historical records on drought in the Northeast are old and diverse and inevitably refer to socio-environmental catastrophes. Regarding the 1979-1983 drought, which left about one million victims, mostly children, the Pastoral Commission of Land (Comissão Pastoral da Terra - CPT), Piauiense Center of Cultural Action (Centro Piauiense de Ação Cultural - CEPAC) and the Brazilian Institute of Social and Economic Analyses (Instituto Brasileiro de Análises Sociais e Econômicas - IBASE) (1988), expressed themselves in this way:

“... We know the real causes of so much pain and suffering, always linked to the concentration of land and water, to the omission and ineffectiveness of government agencies and the perversity of the politicians who occupy their leadership positions ... overcoming the misery of our people requires deep structural transformations, mainly the distribution of land ... policies oriented to the interests of the people ... and there is no other way to achieve the rights of citizenship than through the popular organization. ...” (CPT; CEPAC; IBASE, 1988, p. 117).

Therefore, a natural adversity such as drought only becomes a social tragedy when social, political and economic conditions favor it (Cerqueira, 1988).

Historically, drought has been interpreted in different ways. On the one hand, since the beginning

of the Republic, it is treated as a result of the inability of society to implement technological solutions to face the hostility of nature, which suggests a geographic-climatic determinism. This perspective - predominant among the government technocracy, the academic community and agribusiness sectors - bases its interventions on water catchment in large and medium-sized reservoirs, technological modernization and increased agricultural productivity (Cerqueira, 1988).

For others, the effects of drought are due to a type of agriculture that is not adapted to the environment. Among these, the agronomists Guimarães Duque (1980) and Araújo Filho (2013) stood out, perhaps as the precursors of agroecology in the academic environment of Ceará and the Northeast.

The forms of peasant organization in the semiarid are equally old and their action has been changing (Scherer-Warren, 1993). In the last thirty years, peasants have resumed and strengthened their communal and union relations with social movements, religious and non-governmental organizations (NGOs) that seek to reconcile socio-cultural, economic and environmental objectives, with emphasis on participation, autonomy and political articulation: a form of positive environment-society co-evolution (Norgaard & Sikor, 2002).

Their joint action has shaped new forms of social organization and resistance, with their own approach to agroecology. ASA¹⁰, a network that brings together a large number of civil society orga-

⁹ Pluriactivity, understood as the combination of agricultural activities with non-agricultural activities, inside and outside the property, by a rural family.

¹⁰ The mission of Brazilian Semiarid Articulation (Articulação Semiárido Brasileiro, ASA in Portuguese) is to strengthen civil society in the construction of participatory processes for sustainable development and coexistence with the Semiarid referenced in cultural values and social justice. ASA developed this proposal for the defense of the right to water - food necessary for life and input for the production of other foods - which has become a force-gathering device for this network. The main reason for the success of ASA's actions is the decentralized management of available resources according to local needs. This management is carried out by many networks of different sizes, made up of grassroots organizations - associations, trade unions, women's groups, youth groups and other organizational forms. In this way, a political action generated by the communities is built (<https://www.asabrasil.org.br/>).

nizations, stands out as a regional social expression. These organizations have been building a concept and practices of coexistence with the semiarid, as opposed to the notion of fighting drought based on large dams and irrigation. Coexistence with the semiarid is thus a banner, considered a paradigmatic transition from a utilitarian economic rationality to a socio-environmental rationality of sustainability, which occurs in the midst of the exhaustion of conceptions and models historically formulated and defended by power groups (Silva, 2007; 2010). At the local level, this strategy seeks the constitution of diversified, decentralized and self-controlled reserves of water, food, seeds and fodder, based on the management of high agrobiodiversity and the functional integration of the different agricultural subsystems (Gamarra-Rojas & Fabre, 2017).

6. Mobilizing themes of agroecology in Ceará

In Ceará, a state that is part of the Brazilian semiarid region and has several ASA member organizations, there has been significant progress in agricultural and social experiences and technologies adapted to the semiarid environment. The creation of community revolving funds, supported by solidarity economy programs, granted credit for small projects in rural communities, many of them focused on raising small animals and handicrafts, involving women and young people.

Several families are involved in agroecological production thanks to cisterns and small dams or tanks that capture rainwater and, more recently,

to family systems for reusing gray water¹¹. Allied to the interventions, mobilization, technical training and social communication actions have been responsible for the insertion of men and women in spaces of political influence, knowledge exchange, commercialization in agroecological markets and for the improvement of family nutrition.

Thus, apparently, there is a shift towards a socio-environmental rationality of sustainability in which agroecology emerges as a historical necessity and takes shape in the framework of the struggle of rural peoples in defense of their territories and of another paradigm of development (Rosset & Barbosa, 2019).

The topics addressed below correspond to issues that have been mobilizing agroecology social actors in the semiarid of Ceará and are related to several of the key drivers that have brought agroecology to a larger scale in the Latin American sphere, which, as identified by Mier y Terán *et al.* (2021), include: recognition of a crisis that motivates the search for alternatives; social organization; constructivist learning processes; effective agroecological practices; mobilizing discourses; external allies; favorable markets; and favorable opportunities and policy frameworks.

6.1. Women and young people in the countryside

Rural women and youth, inserted in patriarchal structures, seek in agroecology foundations for more harmonious relationships within societies and with nature (Nunes da Silva, 2017; Fernandes *et*

¹¹ The implementation of 'bio-water' systems stems from the growing demand for efficient use of increasingly scarce water resources, promoting both qualitative management (treatment of domestic effluents and gray water) and quantitative management (reuse of gray water for irrigation), with an impact on the health and food and nutritional security of vulnerable families.

al., 2019). These social subjects form the basis for a sustainable future, as women, due to their role in health and food, are the first to understand and adopt more sustainable production methods, such as mandalas¹² (Lima & Gamarra-Rojas, 2017; Dobe *et al.*, 2020) and domestic yards that sometimes expand throughout the agroecosystem (Fernandes *et al.*, 2019). Young people align individual projects with those of family socioeconomic reproduction (Nunes da Silva, 2017) and have a higher educational level, favoring their productive inclusion in managerial and marketing areas (Gamarra-Rojas *et al.*, 2017).

The issues of rural youth and succession in family farming have been occupying a prominent place in the agenda of trade union movements and organizations that advise landless, quilombos and indigenous people. Young people from the countryside and the city have come together in networks, which constitute political spaces for the qualification of these subjects for the defense of rights, political influence and experiences in agroecology.

For example, the 'Balanço do Coqueiro' is an initiative of young people from the semiarid region of Ceará that works on rural identity through the cultivation, transformation and commercialization of coconut products. In addition to contextualized education programs and the promotion of productive projects, a policy to strengthen the identity of these young people has become fundamental.

In 2019, the State Plan for Youth and Rural Succession was established, which aims to integrate and articulate policies, actions and programs meant to guarantee the rights of rural youth and promote rural succession (Ceará, 2019).

Women agroecological workers reflect and debate on their experiences of production, citizenship and social inclusion, as well as elaborate proposals in training spaces and instances of power such as the Movement of Rural Women Workers of the Northeast. The areas near the residences may represent 'the place' of agroecological expression of agroecosystems, which are important for the food and nutritional security of rural and urban populations.

Given the predominance of smallholdings in conditions of water scarcity, domestic yards assume relevance for the maintenance of rural families with autonomy and equity, which can generate food diversity, such as vegetables and rainfed crops in consortium with fruit trees and small animals, providing monetary and non-monetary income (Gamarra-Rojas *et al.*, 2017; Silva *et al.*, 2020). The alliance between agroecology and feminism as political discourse and practice becomes a prerogative for the affirmation of women in the agroecological movement (Fernandes *et al.*, 2019).

6.2. Agrobiodiversity management

Agrobiodiversity can be understood as "the exploited portion of biodiversity, represented by a set of ecosystems and organisms that have strong relationships with humans, and which can be domesticated, semi-domesticated, cultivated or managed by humans" (Stella *et al.*, 2006, p. 44).

As seen in this text, the Brazilian semiarid region is a center of origin and diversification of

¹² Mandala is a circular farming technology originated in India, Pakistan and regions of the Americas (Paz *et al.*, 2010). This form of agriculture arrived in Ceará in 2008, with the proposal of food production and income generation, without the use of pesticides and ensuring the rational

species relevant to agriculture and food that are threatened, whether by the monopoly in the production and distribution of seeds, by the destructuring of traditional agroecosystems, by transgenic flow (Fernandes *et al.*, 2023), or other causes.

The social actors of agroecology, aware that the expansion of agribusiness, hybrid seeds and transgenics threaten the co-evolution of this heritage of humanity, become guardians of native seeds, fighting for the guarantee of non-contamination of their gardens with transgenics, for programs and projects for the structuring of seed houses and seed banks, and resources for collective seed production gardens.

Thus, due to the growing risk of losing the diversity of crops and domestic animals adapted to the semiarid, the conservation of agrobiodiversity in communal houses or creole seed banks constitutes a peasant strategy for autonomy, security and food sovereignty.

It is understood that the communal seed houses are part of the so-called in situ/on farm conservation as a strategy that allows maintaining and recovering viable populations of species in their own environments, complementary to ex situ conservation, which means the conservation of the components of biological diversity outside their natural habitat (Boef, 2007; London, 2014), generally carried out by agricultural research institutions.

In Ceará there are five Seed Exchange Networks that articulate 152 seed houses, located in the territories of Cariri, Centro Sul, Vale do Curu, Vale do Acaraú and Ibiapaba. In this context, a state network is being reorganized, which may incorporate 324 seed houses, according to a mapping carried out in 2020 by the Working Group of Creole Seeds of the Cearense Forum for Life in the Semiarid

Region. These networks, accompanied by Caritas and the trade union movement, were protagonists of the debate and struggle for the approval in 2019 of the State Policy to Encourage the Formation of Community Houses and Creole Seed Banks (Ceará, 2020).

With genetic contamination being one of the most prominent threats, this issue tends to become more relevant in the scope of the Ceará Seed Network. Fernandes *et al.* (2023) argue that the transgenic flow can be reduced by approving and enforcing more effective coexistence rules that consider the areas of cultivation of local varieties also as seed-producing areas, in addition to full disclosure of the origin of commercial seeds.

6.3. Nutrient recycling and subsystem integration

In the semiarid region of Ceará maize, cassava and beans predominate among rainfed annual crops and generally few resources are used to maintain soil fertility, resulting in negative nutrient balances in these plant production systems (Cunha, 2017). In agroecological systems, the use of organic fertilizers and biomass reuse is widespread in Ceará, although only 15% of farmers overall report using some type of organic fertilizer (IBGE, 2017). Part of this problem can be attributed to limited financial resources for investment, although, reuse practices of residues generated in other subsystems within the agroecosystem, which would require few resources to be used, are rarely observed (Cunha, 2017; Camelo & Blum, 2018). Thus, nutrient depletion could be minimized by increasing integration between agroecosystem subsystems (Camelo & Blum, 2018).

Despite the fact that annual crop production systems are important for the subsistence of family farmers in the semiarid region, these crops occupy a low proportion of the total area of properties. For example, in Ceará, only 9.5% of the total area of the state is occupied by annual crops, while more than 34% of the area is occupied by pastures (IBGE, 2017). These pastures are predominantly constituted by natural vegetation. Pastures in natural vegetation systems are often used above their carrying capacity, leading to soil degradation processes (Araújo Filho, 2013). Despite this, it is argued that native plant species, with proper management, have great potential for sustainable use, due to their adaptation to semiarid conditions (Araújo Filho, 2013). In addition, the expansion of agrobiodiversity has proven to be efficient in promoting nutrient recycling and maintaining crop fertility in agroforestry systems (Aguar *et al.*, 2011; Mendes *et al.*, 2019).

Among rainfed fruit species, cashew cultivation is prominent in the Semiarid Region (IBGE, 2017). Traditional cashew plantations are constituted by the cultivation of the so-called "Giant Cashew", with wide genetic variability, under a management that resembles an agrosilvopastoral system, where fertilization practices or control of phytophagous microorganisms and insects are rarely adopted (Gamarrá-Rojas *et al.*, 2017). In theory, the giant cashew crop alone, although it does not receive fertilization, has a small negative impact on soil fertility, because it is a system with low product extraction by harvesting nuts and large trees, which are capable of exploiting large volume and depth of soil. However, as giant cashew is often associated with animal husbandry and annual crops, it raises the same concerns about land degradation

associated with animal husbandry in natural areas, as discussed above.

Although giant cashew crops still predominate in the area, they are gradually being replaced by the so-called "early dwarf cashew". This system consists of growing low-growing plants, selected in breeding programs and densely planted. The selected clones have a pseudo-fruit of greater size and homogeneity, favoring the market of the 'fruit' in natura; they are preferred by the nut industry based on yield, ease of processing and, mainly, by the size pattern, which makes the cutting of the fruit easier.

The nutrient balance in dwarf cashew crops is generally positive, due to low nutrient export through the nuts and the use of organic fertilizers (Pereira, 2017). However, soil conservation concerns remain due to the use of management practices that keep the area unprotected.

It should also be taken into account that these cashew crops have low genetic variability. It is estimated that cultivar CCP 076 is grown in about 90% of these areas in Ceará, a fact that can compromise the health of agroecosystems, when phytophagous previously little disseminated can become pests, such as powdery mildew, a fungal disease that has become a serious issue (Lima, 2017).

Agricultural research responses are usually based on the search for resistant genotypes, combined with the use of pesticides, as phytophages and parasites, previously little perceived as pests, now acquire such a status.

Changing this perspective implies unraveling and valuing traditional forms of cashew management, including integration with annual crops and livestock during the rainy season, in addition to providing value-adding strategies that allow farmers to devote more attention to their crops, without

yielding to the imperative of corporations that determine the adoption of capital-intensive technologies, with consequent increase in intermediary consumption, with no guarantee of remuneration to farmers, who sell low-value-added raw materials to agroindustrial oligopsonies.

The case of cashew nuts in agroecosystems in Ceará illustrates the tensions between different management practices and proposals. One is based on homogeneous systems, the commercial product and the solution of specific problems. The other approaches the situation in a multidimensional and systemic way, typical of agroecology.

6.4. *Solidarity markets*

Agroecological production in Ceará presents a hierarchical order of its purposes, based on self-consumption, followed by commercialization and donation (Silva *et al.*, 2018), while organic production is mainly oriented towards commercialization (Morales Mora, 2018). However, both strategies are used, reflecting social structures that associate market exchange and reciprocity practices.

Farmers, technicians, managers and researchers dedicated to agroecology recognize the existence of differentiated markets (Morales Mora, 2018). The one with the greatest preference and dynamism is the local market, composed of agroecological or organic fairs and the community that promotes neighborhood exchanges, constituting

short marketing channels, as an alternative to face the growing commodification of agrifood markets.

As an example, in the territory of Vale do Curu e Aracatiaçu in Ceará there are nine fairs, the oldest of which is the 'agroecological and solidarity fair of Itapipoca', which is 15 years old. It is composed of 24 families from the Ceará municipalities of Itapipoca, Trairi and Tururu who, organized in a network, meet weekly in the main square to sell their products, earning monthly incomes above the minimum wage. Second in importance, the global market is represented by supermarkets, retail, the foreign market and online shopping. Finally, the institutional market, stimulated by public entities through the Food Acquisition Program (PAA) and the National School Food Program (PNAE) (Morales Mora, 2018).

These markets are usually related to certification mechanisms¹³, promoted by individuals or state agencies, such as the Biodynamic Certification Institute (IBD Certificações), the Technical Assistance and Rural Extension Company (Ematerce) and the Ceará Organic Production Commission (CPOrg-CE), which can act as a mechanism of inclusion, expanding marketing opportunities at differentiated prices (30% or more in the public procurement programs PAA and PNAE), or of exclusion of farmers from the organic market, either because of limitations to pay for the service or because they are outside the organizations that provide it (Lima & Pinheiro, 2004).

¹³ The certification of organic products in Brazil was established in law in 2003, while the regulation occurred in 2007. Among the particularities of the organic legislation in Brazil is the possibility of peer certification, which consists of Participatory Guarantee Systems (SPG) that, in the case of direct commercialization by farmers, is carried out through Social Control Organizations (OCS). In the case of indirect commercialization, a Participatory Organic Conformity Assessment Body (OPAC) is required. In addition to the SPG, organic products in Brazil are certified by the so-called third party certifiers, which are paid for the provision of evaluation services of the production agents as established by law, following the Brazilian regime for the domestic market or the regime of the country of destination for the international market.

6.5. Agroecosystem studies and action research

The agroecosystem is an ecosystem modified for the purpose of producing goods and services, generally identified with the agricultural production unit and constitutes the basic unit of analysis and intervention in agroecology (Gliessman, 2002). Agroecosystem analysis (Conway, 1986), as an action-research methodology, favors the observation, analysis and understanding of complex realities in order to classify, compare and support proposals for intervention and monitoring of changes, such as the

conversion of conventional production systems to sustainable ones. In Ceará, as well as in other states of the semiarid Northeastern Region, there is a growing number of agroecosystemic, participatory studies, with different purposes, at different spatial levels and, more recently, incorporating Social Metabolism (González de Molina & Toledo, 2014) - an analogy to biological metabolism - as a conceptual framework for socio-ecological transformations. This seeks to describe and quantify the flows of matter and energy between society and nature, but also intangible processes such as institutions and norms (Table 1).

TABLE 1 - Examples of agroecosystem analysis in Ceará.

Title	Objective	Reference
The settlers' relationship with water through the Açude Velho, Barra do Leme Settlement.	To understand the relationship of the inhabitants of the Barra do Leme settlement with water through its metabolism with the Açude Velho.	Gurgel Júnior (2022)
Sustainability of organic and conventional irrigated systems based on family farming.	To comparatively evaluate two irrigation production systems, one organic and the other conventional, using economic, social and environmental sustainability indicators, in Guaraciaba do Norte, Ceará.	Gomes <i>et al.</i> (2021)
Evaluation of an agri-food system in the Brazilian semiarid region: an economic-ecological perspective.	Evaluate a family agroecosystem in Itapipoca, Ceará, through economic-ecological analysis.	Dobe <i>et al.</i> (2020)
Animal production in the family farming economy: a case study in the Brazilian semiarid region	Comprehend the importance of cattle raising for the economy of family farming in the Sítio Areias, establishing relationships with the Territory and the Municipality of Sobral, Ceará.	Silva <i>et al.</i> (2018)
Nutrient flows in small-scale farm production systems from Northeastern Brazil	To identify strategies for phosphorus and potassium recycling in agricultural systems in Northeastern Brazil.	Camelo & Blum (2018)
Energy efficiency with an agroecological approach in agroecosystems in the Brazilian semiarid region.	To compare the sustainability of two family agroecosystems in Pentecoste and Quixeramobim, Ceará, through ecological energy analysis.	Matias (2017)
Dynamics and differentiation of production systems in the Brazilian semiarid region: agriculture in the municipality of Pentecoste, Ceará.	Identify the types of farmers in Pentecoste, Ceará, characterize their agroecosystems and analyze their social renewal.	Bento <i>et al.</i> (2017)

SOURCE: Prepared by the authors.

The examples shown in Table 1 illustrate innovations in the orientation of scientific work and in the training of human resources in the area of Agricultural Sciences at the Federal University of Ceará, moving from analyses focused on specific crops and few variables - generally productivity and yield - to a systemic analysis of multiple factors and scales, historically located, where native and adapted agrobiodiversity, nutrient and energy flow and water have been gaining prominence in the conflicting issues involving the relationship between environment, society and economy.

A related innovative aspect is the growing interdisciplinarity, involving different academic departments and courses of the University - such as soils, agricultural engineering, agricultural socio-economics and ecological economics - and social actors of agricultural development. Young university students who have gone through these action-research experiences have entered the job market with a sustainable perspective on agriculture.

Two initiatives involving farmers and technical advisors in action-research in agroecosystems in Ceará are worth mentioning. Cetra developed the Agroecological System of Integrated Knowledge (Saci), which is a database of agroecosystems supported by that organization, and also works with the 'Agroecological Notebook' in domestic backyards managed by women (Fernandes *et al.*, 2019). Both strategies have affinity with the principles and tools of agroecosystem analysis and constitute forms of participatory research that, supported by continued practice, develop the data recording and analysis capacities of the field subjects involved, promoting social awareness of the active participation of women and youth in the production of agroecological knowledge and in the economy.

6.6. Rural extension and sustainable agriculture policies

The public policies aimed at modernization initiated in the 1970s, based on the technology diffusion model, in which the technical assistance and rural extension agent (ATER) is a fundamental part of the process, favor large estates and intensify socioeconomic inequalities in rural areas. In turn, the strengthening of family farming and meeting society's demands for sustainable agriculture have received a significant boost from the National Policy for Technical Assistance and Rural Extension - PNATER (Brazil, 2010). This 'new' ATER is guided by another paradigm for the construction of agricultural and rural knowledge, compatible with the concept of sustainable rural development and based on agroecology. To this end, ATER agents should abandon the diffusionist approach, adopting participatory methodologies and a multidisciplinary and systemic approach (Pinheiro *et al.*, 2023).

What normatively seems simple, in practice is configured as a challenge. A study of agroecological knowledge production conducted in 2018 revealed that in Ceará there were 34 ATER organizations accredited in the Special Secretariat of Family Agriculture and Agrarian Development (SIATER1), of which approximately 60% presented affinities with the guidelines and objectives of the aforementioned PNATER (Pinheiro *et al.*, 2023). Among these are the organizations that have been incessantly innovating in the Semiárid, as is the case of the ATER online in the context of the Covid-19 pandemic (CAATINGA, 2021).

However, this picture cannot be generalized (Alves *et al.*, 2015), as it was found that this profile

is more present in the work of the so-called agroecology NGOs, being necessary to seek to expand the agroecological perspective to the totality of ATER organizations in Ceará if agroecology is to be consistently disseminated in the semiarid (Pinheiro *et al.*, 2023).

With the launch of the PNAPO - National Policy for Agroecology and Organic Production (Brazil, 2012), the country renewed its commitment to sustainable agriculture and became the first nation to create a specific state policy to promote agroecology and organic production, in cooperation between States, Federal District and Municipalities, civil society organizations and other private entities. Its objective is to integrate, articulate and adapt policies, programs and actions that induce the agroecological transition and organic production, contributing to sustainable development and improving the quality of life of society, through the sustainable use of natural resources and the supply and consumption of healthy food.

Ongoing actions of the government of Ceará, such as the Paulo Freire project, financed by the International Fund for Agricultural Development (IFAD), and other initiatives mentioned earlier in this text, include agroecology in their guidelines. In 2020 the National Agroecology Articulation identified in Brazilian municipalities policies and programs that contribute to agroecology and support family farming (ANA, 2021). In Ceará there are 39 municipal initiatives that address 17 themes, such as: Education in agroecology; Support for fairs and short marketing channels; Cisterns and other forms of water storage; Institutional purchases and demand generation tools for family farming production; Technical assistance and agroecological rural

extension; Defense of women's rights; Agroforestry and composting. This 'discovery' illustrates proposals for sustainable agriculture from the municipality, where states, organizations and civil society territorialize projects, programs and policies.

However, much remains to be done, since for a decade the agroecological movements of Ceará have been promoting the elaboration of a State Agroecology Policy that, following the example of the PNAPO, brings together and coordinates the different initiatives, without yet having the decisive support of the governments that periodically succeeded one another in Ceará. The situation reflects the political contradictions of the Brazilian state (Diniz & Rozendo, 2019) and of Ceará in particular, as there is a notable difference between the large volumes of public investment that benefit agribusiness, on the one hand, and the modest resources earmarked for sustainable agriculture, on the other.

7. Synthesis and prospection for research and action.

From the historical analysis of the main productive cycles established not only in the Brazilian Semiarid but also, particularly, in the Cearense one, it is possible to affirm that the different economic cycles were determined by rationalities that disregarded the natural vocation of the territories, in such a way that the agents defining public and private investments always visualized drought as an unnatural, unexpected event that should be overcome by the resident populations, before assuming a position of coexistence with semiaridity.

This condition has persisted to the present day, worsening with the developmentalist models of agricultural modernization, which implemented pharaonic projects highly dependent on investments in water structures and energy and material inputs that make societies and the environment they inhabit more fragile, since the intensive use of external inputs generates dependence and eliminates local skills and knowledge to manage existing resources in the landscape, such as biodiversity, eating habits, handicrafts and many other devices that guarantee the autonomy and freedom of the people.

The theoretical framework of agroecology allows us to argue that the solution to the water crises experienced in semiarid regions (droughts) involves the valorization of the material and immaterial assets of the territories. The first of these, but not the only one, refers to defining productive strategies that make efficient use of the different types of water available, without losing sight of decentralized storage strategies, capable of reducing the demand and urgency of supply for domestic and productive consumption. This explains the success of the 'One Million Cisterns' program of the Semiarid Association (ASA), as presented above.

In addition to storing water, semiarid agriculture needs to prioritize moisture, nutrient and energy conservation strategies through biogeochemical processes carried out by plants adapted to arid and hot conditions, so that native species as a whole and some native or exotic species of economic importance such as Anacardiaceae (umbu, cajá, cashew), arboreal vegetables (sabiá, moringa, leucena, gliricidia), cacti (forage palm, xique-xique, mandacaru) need to be prioritized in agroecosystems for food

production, energy and environmental services provided by nutrient recycling processes.

Another strategic issue in the agroecological management of agroecosystems is the conservation of the so-called 'passion seeds' or 'creole seeds', which serves as an instrument to guarantee the genetic conservation of seeds of rainfed crops, such as corn, beans and peanuts. The seed houses in the rural communities of the Semiarid are potentially capable of aggregating families and strengthening the social capital of rural communities.

Agroecology is moving in the direction of adding to the productive processes, pedagogical aspects of social construction of knowledge, being the experiences accumulated by the farmers potentialized in terms of scope and replicability to the extent that institutions such as NGOs, universities and research institutes approach, perceive and systematize the quality of these processes, which invariably break with the logic of normal science and move towards the construction of a science with the people.

Although the organizational structure of rural communities is still loaded with patriarchal and chauvinistic notions, the agroecological perspective enables women and young people to break with these traditions, recognizing the role of undervalued factors in the economy of rural families and communities, such as domestic services, production for family consumption or productive and organizational processes that transcend agricultural activities, such as agro industrialization and commercialization of production for value addition purposes.

These processes aimed at adding value to production require the participation of all members of the household and collective action, since

production is often isolated and the other stages of the agrifood system (distribution, marketing and consumption) do not have actors involved in the agroecological transition effort. To deal with this difficulty, most agroecological rural establishments take on the other stages of the agroecological system, seeking to market their production directly to the final consumer.

Thus, the trajectory of sustainable agriculture in the warm semiarid lands of Ceará goes through a process of building agroecological knowledge and awareness, based on practices and debates on coexistence with the semiarid environment, where farmers, agroecological movements and academic sectors tend to acquire an increasingly prominent role in social and technological experimentation and in the formulation of public policies for agricultural and rural sustainability.

The notion of coexistence with semiaridity, which we sought to make explicit in this essay as a specific approach to agroecology, is related to water from a multidimensional and transversal perspective of coevolution between environment and society. The agro-ecosystem approach, contextualized by the conceptual framework of social metabolism, particularly water metabolism, has the potential to contribute to the understanding of the interfaces between environment, society and economy in the semiarid region.

The close relationship between the themes addressed in this article and the drivers of Agroecology in Latin America suggests that despite the enormous diversity of environments, biomes, peoples and agricultures, there is considerable strategic and political affinity, favoring the closeness of subjects excluded from modernization in this region.

In turn, ongoing research in the NEAEE - which includes: a typology of the agroecological transition of farmers accompanied by rural development organizations; the dynamics of creole seed houses for the conservation and sustainable use of native agrobiodiversity and adapted to Semiarid and; the relationships between mercantile and solidarity practices in commercialization processes of agroecological production - shall shed 'new' information on the processes that lead to sustainability or unsustainability of agricultures in semiarid environments, from the cultivation units to the environments of elaboration and implementation of public policies.

Regarding public policies and a favorable political environment for agroecology in Ceará, it should be said that the environmental legislation for the Caatinga biome is partially implemented. There is no legislation that discourages the practice of predatory agriculture or that stimulates and rewards farms and farmers that either benefit the environment or provide environmental services.

References

ABRASCO — Associação Brasileira de Saúde Comunitária. *Dossiê ABRASCO: um alerta sobre os impactos dos agrotóxicos na saúde. Parte 1 - Agrotóxicos, Segurança Alimentar e Nutricional e Saúde.* Rio de Janeiro: ABRASCO, 2012.

Aguiar, M. I.; Vale, N. F. L.; Oliveira, T. S.; Campanha, M. M. Produção de serapilheira e ciclagem de nutrientes em sistemas agroflorestais. In: *Anais do Congresso Norte e Nordeste de Pesquisa e Inovação Tecnológica - CONNEPI*, 6. Natal: SETEC/MEC, 2011.

Almeida, F. *Lei de terras.* Arquivo Nacional; Memória da Administração Pública Brasileira - MAPA, 2015. Disponível em: <<http://mapa.an.gov.br/index.php/menu-de-categorias>>

-2/279-lei-de-terras.> Acesso en: ago. 2023.

Altieri, M. A. *Agroecologia: bases científicas para una agricultura sustentable*. Montevideo: Editorial Nordan-Comunidad, 1999.

Alves, M. O.; Bursztyn, M.; Chacon, S. S. Ação coletiva e delegação de poder no semiárido nordestino: papel de lideranças locais e assessores externos numa comunidade rural. *Revista de Economia e Sociologia Rural*, 53(3), 409-432, 2015. doi: 10.1590/1234-56781806-9479005303003

ANA — Articulação Nacional de Agroecologia. *Municípios agroecológicos e políticas de futuro: iniciativas municipais de apoio à agricultura familiar e à agroecologia e de promoção da segurança alimentar e nutricional*. Rio de Janeiro: ANA, 2. ed., 2021. Disponível en: <<https://agroecologia.org.br/wp-content/uploads/2021/01/Municipios-Agroecologicos-e-Politicass-de-Futuro.pdf>> Acesso en: ago. 2023.

Andrade, S. M. C. A questão agrária no nordeste. *São Paulo em Perspectiva*, 11(2), 109-118. 1997.

Antonino, A. C. D.; Audry, P. *Utilização de água no cultivo de vazante no semiárido do nordeste do Brasil*. Recife: Editora da UFPE; IRD. 2001.

Araújo Filho, J. A.; Sampaio, E. V. S. B. *Sistemas de uso da terra e seus impactos sobre os ecossistemas do semiárido nordestino*. Recife: MDA/SDT/Projeto Sertão; FIDA; GEF, 2004.

Araújo Filho, J. A. *Manejo pastoril sustentável da caatinga*. Recife, PE: Projeto Dom Hélder Câmara, 2013. Disponível en: <<http://portalsemear.org.br/publicacoes/manejo-pastoril-sustentavel-da-caatinga/>> Acesso en: ago. 2023.

Barroso, N. J. Pecuária. In: Hereda, M. G. C.; Domingues, A. J. P. (Orgs.). *Geografia do Brasil*. Grandes regiões Meio-Norte e Nordeste. Rio de Janeiro: IBGE, 1962. p. 227-250.

Bento, J. A. N.; Gamarra-Rojas, G.; Lemos, J. J. S.; Casimiro Filho, F.; Mattos, J. L. S. Dinâmica e diferenciação de sistemas de produção no semiárido brasileiro: agriculturas do município de Pentecoste, Ceará. *Desenvolvimento em Questão*, 15(41), 416-456, 2017. doi: 10.21527/2237-6453.2017.41.416-456

Boef, W. S. Biodiversidade e agrobiodiversidade. In: Boef,

W. S. et al. (Orgs.). *Biodiversidade e agricultores: fortalecendo o manejo comunitário*. Porto Alegre, RS: L&PM, 2007. p. 36-40.

Braga, R. *Plantas do nordeste, especialmente do Ceará*. Fortaleza, CE: Imprensa Oficial, 2. ed., 1960.

Brasil. *Lei nº 12.188, de 11 de janeiro de 2010*. Institui a Política Nacional de Assistência Técnica e Extensão Rural para a Agricultura Familiar e Reforma Agrária – PNATER e o Programa Nacional de Assistência Técnica e Extensão Rural para a Agricultura Familiar e Reforma Agrária – PRONATER, altera a Lei nº 8.666, de 21 de junho de 1993. Brasília: DOU de 12/01/2010.

Brasil. *Lei nº 11.326, de 24 de julho de 2006*. Estabelece as diretrizes para a formulação da Política Nacional da Agricultura Familiar e Empreendimentos Familiares Rurais. Brasília: DOU de 25/07/2006.

Brasil. *Decreto nº 7.794, de 20 de agosto de 2012*. Institui a Política Nacional de Agroecologia e Produção Orgânica. 2012. Disponível en: <http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2012/decreto/d7794.htm> Acesso en: ago. 2023.

CAATINGA — Centro de Assessoria e Apoio aos Trabalhadores e Instituições Não-Governamentais Alternativas. *Práticas de ATER remota no contexto da pandemia da Covid-19: potencialidades, desafios e recomendações*. Ouricuri, PE: Caatinga; FIDA, 2021.

Camelo, G. G. S.; Blum, J. Nutrient flows in small-scale farm production systems from northeastern Brazil. *Agroecology and Sustainable Food Systems*, 42(9), 963-981, 2018. doi: 10.1080/21683565.2018.1468382

Caporal, F. R.; Costabeber, J. A. Agroecologia: enfoque científico e estratégico. *Agroecologia e Desenvolvimento Rural Sustentável*, 3(2), 13-16, 2002. Disponível en: <<https://www.projetovidanocampo.com.br/agroecologia/agroecologia.pdf>> Acesso en: ago. 2023.

Cascudo, L. C. *História da alimentação no Brasil*. São Paulo, SP: Global editora, 4. ed., 2011.

Ceará. *Lei nº 17.179, 15.01.2020*. Dispõe sobre a política estadual de incentivo à formação de casas e bancos comu-

nitários de sementes crioulas e mudas. Fortaleza: DO de 16/01/2020.

Ceará. *Projeto de Lei nº 3/19*. Institui o Plano Estadual de Juventude e Sucessão Rural. Assembleia Legislativa do Estado do Ceará, 2019. Disponível em: <https://www2.al.ce.gov.br/legislativo/tramit2019/pi3_19.htm> Acesso em: ago. 2023.

Cerqueira, P. C. L. A seca no contexto social do Nordeste. In: CPT; CEPAC; IBASE - Comissão Pastoral da Terra; Centro Piauiense de Ação Cultural; Instituto Brasileiro de Análises Sociais e Econômicas. *O genocídio do Nordeste 1979 - 1983*. São Paulo: Edições Mandacaru; CPT; CEPAC; IBASE, 1988. p. 30-73.

Conterato, M. A. *et al.* O consumo intermediário na agricultura: uma comparação entre agricultura familiar e não familiar no Brasil e nas regiões sul e nordeste. In: Schneider, S.; Ferreira, B.; Alves, F. (Orgs.). *Aspectos multidimensionais da agricultura brasileira: diferentes visões do Censo Agropecuário 2006*. Brasília: Ipea, p. 135-164, 2014.

Conway, G. R. *Agroecosystem analysis for research and development*. Bangkok: Winrock International, 1986.

CPT; CEPAC; IBASE - Comissão Pastoral da Terra; Centro Piauiense de Ação Cultural; Instituto Brasileiro de Análises Sociais e Econômicas. *O genocídio do Nordeste 1979 - 1983*. São Paulo: Edições Mandacaru; CPT; CEPAC; IBASE, 1988.

Cruz, M. A. O. M.; Cabral, M. C. C.; Silva, L. A. M.; Barreto Campello, M. L. C. *Diversidade da mastofauna no estado de Pernambuco*. In: Tabarelli, M.; Silva, J. M. C. da (Orgs.). Diagnóstico da biodiversidade de Pernambuco. Recife: SECTMA, Ed. Massangana, p. 557-579, 2002.

Cunha, I. M. L. *Fluxos e teores de nutrientes em sistemas de cultivos de produtores rurais em descapitalização*. Fortaleza, Dissertação (Mestrado em Ciência do Solo) - UFC, 2017. Disponível em: <http://www.ppgsolos.ufc.br/images/2017_dis_imlimacunha.pdf> Acesso em: ago. 2023.

Diniz, P.; Rozendo, C. Panorama da Política Nacional de agroecologia e produção orgânica na última década. *Boletim da Sociedade Brasileira de Economia Ecológica*, 39, 53-61,

2019. Disponível em: < <http://ecoeco.org.br/wp-content/uploads/2019/07/ECOECO-BOLETIM-V3-0507-1.pdf> > Acesso em: ago. 2023.

Dobe, E. K.; Chagas, T. P.; Nogueira, F. C. B. Avaliação de um sistema agroalimentar no semiárido brasileiro: um olhar econômico-ecológico. *Agroecossistemas*, 12(2), 01-23, 2020. ISSN online 2318-0188

Duque, J. G. *O Nordeste e as lavouras xerófilas*. Mossoró: ESAM; Fundação Guimarães Duque, 3. ed., 1980.

Elias, D. Integração competitiva do semiárido cearense. In: Elias, D.; Sampaio, J. L. F. (Orgs.) *Modernização excludente*. Fortaleza: Ed. Demócrito Rocha, 2002.

Evangelista, F. R. *A agricultura familiar no Brasil e no Nordeste*. Fortaleza: BNB/ETENE, 2000.

Fernandes, G. B.; Silva, A. C. de L.; Maronhas, M. E. S.; Santos, A. da S. dos; Lima, P. H. C. Fluxo transgênico: desafios para a conservação on farm de variedades crioulas de milho no Semiárido brasileiro. *Desenvolvimento e Meio Ambiente*, 61, 133-160, 2023. doi: 10.5380/dma.v61i0.85886

Fernandes, S. L. R.; Esmeraldo, G. G. S. L.; Jalil, L. M. Mulheres, agroecologia e convivência com o semiárido: quintais produtivos e a caderneta agroecológica a desvendar forças sociais, produtivas e humanas. *Boletim da Sociedade Brasileira de Economia Ecológica*, 39, 62-68, 2019. Disponível em: < <http://ecoeco.org.br/wp-content/uploads/2019/07/ECOECO-BOLETIM-V3-0507-1.pdf> > Acesso em: ago. 2023.

Fortini, R. M. *Um novo retrato da agricultura familiar do semiárido nordestino brasileiro: a partir dos dados do censo agropecuário 2017*. Viçosa, MG: IPPDS, UFV, 2020.

Furtado, C. *Formação econômica do Brasil*. Rio de Janeiro: Ed. Fundo de Cultura, 6. ed., 1964.

Gamarra-Rojas, C. F. L.; Gamarra-Rojas, G. *Manejo da caatinga no assentamento Moacir Lucena*, RN. Recife: MDA/SDT/Projeto Dom Helder Câmara; FIDA. 2004.

Gamarra-Rojas, G.; Gamarra-Rojas, C. F. L. Conservação e uso de frutíferas nativas de Pernambuco. In: Tabarelli, M.; Silva, J. M. C. da (Orgs.). *Diagnóstico da biodiversidade*

- de Pernambuco. Recife: SECTMA, Ed. Massangana, p. 661-673, 2002.
- Gamarra-Rojas, G.; Freire, A. G.; Moreira, J. M.; Almeida, P. Frutas nativas: de testemunhos da fome a iguarias na mesa. *Agriculturas*, 1(1), 15-18, 2004. Disponível em: <<http://aspta.org.br/files/2014/10/Artigo-5-Frutas-nativas-de-testemunhos-da-fome-a-iguarias-na-mesa1.pdf>> Acesso em: ago. 2023.
- Gamarra-Rojas, G.; Fabre, N. Agroecologia e mudanças climáticas no trópico semiárido. *Redes*, 22(2), 174-188, 2017. doi: 10.17058/redes.v22i2.9359
- Gamarra-Rojas, G.; Silva, N. C. G.; Vidal, M. S. C. Contexto, (agri)cultura e interação no agroecossistema familiar do caju no semiárido brasileiro. *Cadernos de Ciência & Tecnologia*, 34(3), 315-338, 2017. doi: 10.35977/0104-1096.cct2017.v34.26382
- Gamarra-Rojas, G. Agroecologia. *Boletim da Sociedade Brasileira de Economia Ecológica*, 39, 04-08, 2019. Disponível em: <http://ecoeco.org.br/wp-content/uploads/2019/07/ECOECO-BOLETIM-V3-0507-1.pdf>
- Gamarra-Rojas, G. Agroecologia no Ceará. *Boletim Informativo do Núcleo Regional Nordeste da Sociedade Brasileira de Ciência do Solo*, 4(2), 39-49, 2020. Disponível em: <<http://www.sbcs-nrne.org.br/publicacoes>> Acesso em: ago. 2023.
- Giacometti, D. C. Recursos genéticos de fruteiras nativas do Brasil. In: *Anais do Simpósio Nacional de Recursos Genéticos de Frutíferas Nativas*, 1992, Cruz das Almas, BA: EMBRAPA-CNPMPF, p. 13-27, 1993.
- Gliessman, S. *Agroecología: procesos ecológicos en agricultura sostenible*. Turrialba: Catie, 2002.
- Gomes, M. D. A.; Costa, R. N. T.; Gamarra-Rojas, G.; Oliveira, F. T. R.; Nunes, K. G. Sustainability of organic and conventional irrigated systems based on family farming. *Irriga*, 1(1), 14-29, 2021. doi: 10.15809/irriga.2021v-1n1p14-29
- Hecht, S. B. The evolution of agroecological thought. In: Altieri, M. A. *Agroecology: the scientific basis of alternative agriculture*. Boulder: West View Press; London: IT Publications, p. 1-20, 1987.
- IBGE — Instituto Brasileiro de Geografia e Estatística. *Censo Agropecuário 2017*. Disponível em: <[https://sidra.ibge.gov.br/pesquisa/censo-agropecu-ario-2017](https://sidra.ibge.gov.br/pesquisa/censo-agropecuario/censo-agropecu-ario-2017)> Acesso em: oct. 2020.
- INCRA; FAO - Instituto Nacional de Colonização e Reforma Agrária; Food and Agriculture Organization. *Novo retrato da agricultura familiar*. O Brasil redescoberto. Brasília: Projeto de Cooperação Técnica INCRA; FAO, 2000.
- IPECE — Instituto de Pesquisa e Estratégica Econômica do Ceará. *Características geográficas, recursos naturais e meio ambiente*, 2016. Disponível em: <http://www2.ipece.ce.gov.br/publicacoes/ceara_em_numeros/2016/territorial/01_Caracteristicas_Geograficas.pdf> Acesso em: ago. 2023.
- González de Molina, M.; Toledo, V. M. *Social Metabolisms: a theory on socio-ecological transformations*. New York, NY: Springer, 2014.
- Gurgel Júnior, L. A. *A relação dos assentados com a água através do Açude Velho, Assentamento Barra do Leme*. Fortaleza, Trabalho de Conclusão de Curso - Graduação (Curso de Economia Ecológica) — UFC, 2022.
- Kageyama, A. et al. O novo padrão agrícola brasileiro: do complexo rural aos complexos agroindustriais. In: Delgado, G. C.; Gasques, J. G.; Villa-Verde, C. M. *Agricultura e políticas públicas*. Brasília: Ipea, 1990, p. 113-223.
- Lima, J. S. *Epidemiologia quantitativa do oídio do cajueiro no clone BRS-189*. Fortaleza, Tese (Doutorado em Agronomia/Fitotecnia) — UFC, 2017.
- Lima, P. J. B. F.; Pinheiro, M. C. A. Abordagem das relações sociais em experiências de produção e comércio de produtos ecológicos no Brasil. In: Küster, A.; Martí, J. M.; Fickert, U. (Orgs.) *Agricultura familiar, agroecologia e mercado no norte e nordeste do Brasil*. Fortaleza: Fundação Konrad Adenauer, DED, p. 51-66, 2004.
- Lima, R. V.; Gamarra-Rojas, G. Camponeses e a mandalla no semiárido brasileiro: reflexões sobre sustentabilidade com base em um estudo de caso com abordagem agroecossistêmica. *Cadernos de Ciência & Tecnologia*, 34(2), 161-195, 2017. doi: 10.35977/0104-1096.cct2017.v34.26326

- Linhares, M. Y. L. Pecuaría, alimentos e sistemas agrários no Brasil (Séculos XVII e XVIII). In: *Arquivos do Centro Cultural Calouste Gulbenkian, Le Portugal et l'Europe Atlantique, le Brésil et l'Amérique Latine. Mélanges offerts à Frédéric Mauro*, Lisboa, Paris, 1995.
- Londres, F. Sementes da diversidade: a identidade e o futuro da agricultura familiar. *Agriculturas*, 11(1), 4-8, 2014. Disponível em: <https://aspta.org.br/files/2014/05/Agriculturas_V11N1.pdf>. Acesso em: ago. 2023.
- Martins, F. H. Extrativismo vegetal. In: Hereda, M. G. C.; Domingues, A. J. P. (Orgs.). *Geografia do Brasil*. Grandes regiões Meio-Norte e Nordeste. Rio de Janeiro: IBGE, 1962. p. 329-354.
- Matias, P. C. *Eficiência energética com enfoque agroecológico em agroecossistemas do semiárido brasileiro*. Fortaleza, Dissertação (Mestrado em Economia Rural) - UFC, 2017. Disponível em: <<http://www.repositorio.ufc.br/handle/riufc/30358>>. Acesso em: may. 2021.
- Mazoyer, M.; Roudart, L. *História das agriculturas no mundo: do neolítico à crise contemporânea*. São Paulo: Ed. UNESP, 2010.
- Mendes, M. M. D. S.; Lacerda, C. F. D.; Fernandes, F. E. P.; Cavalcante, A. C.; Oliveira, T. S. Nutrient input and output in an agroforestry system in a semiarid region of Brazil. *Forestry Research and Engineering: International Journal*, 3(4), 146-152, 2019. doi: 10.15406/freij.2019.03.00091
- Mier y Terán G. C. M. *et al.* Masificación de la agroecología: impulsores clave y casos emblemáticos. *Desenvolvimento e Meio Ambiente*, 58, 480-508, 2021. doi: 10.5380/dma.v58i0.81503
- MMA; SRH - Ministério do Meio Ambiente; Secretaria de Recursos Hídricos. *Programa de ação nacional de combate à desertificação e mitigação dos efeitos da seca: PAN-Brasil*. Brasília: MMA; SRH, 2004.
- Morales Mora, A. E. *Agroecologia e agricultura orgânica na perspectiva dos atores sociais no estado do Ceará*. Fortaleza, Dissertação (Mestrado em Economia Rural) — UFC, 2018. Disponível em: <<http://www.repositorio.ufc.br/handle/riufc/37612>>. Acesso em: ago. 2023.
- Nasuti, S.; Eiró, F.; Lindoso, D. Os desafios da agricultura no semiárido brasileiro. *Sustentabilidade em Debate*, 4(2), 276-298, 2013.
- Norgaard, R. B.; Sikor, T. O. Metodologia e prática da agroecologia. In: Altieri, M. *Agroecologia: bases científicas para uma agricultura sustentável*. Guaíba: Agropecuária, 2002.
- Nunes da Silva, J. Juventudes rurais e agroecologia: um diálogo imprescindível. *Redes*, 22(2), 208-226, 2017. doi: 10.17058/redes.v22i2.9348
- Olinger, G. *Ascensão e decadência da extensão rural no Brasil*. Florianópolis: EPAGRI, 1996.
- Paz, Y. M.; Albuquerque, C. G.; Gomes, R. K. L. *et al.* Sustentabilidade socioambiental da agricultura circular familiar, estudo de caso nas comunidades de Acauã (PB), Frei Damião e Umburanas (PE). In: *Anais da Reunião Anual da SBPC*, 62, Natal: SBPC, 2010.
- Pereira, R. *Resiliência e fluxos de nutrientes em agroecossistemas cultivados com caju na região semiárida do Brasil*. Fortaleza, Dissertação (Mestrado em Ciência do Solo) — UFC, 2017. Disponível em: <<https://ppgsolos.ufc.br/wp-content/uploads/2021/06/dissertaCAo-ricardo-pereira.pdf>>. Acesso em: ago. 2023.
- Pinheiro, B. C. F. S.; Gamarra-Rojas, G.; Mattos, J. L. S.; Lima, F. A. X.; Fernandes, L. E. S. Construção de conhecimento agroecológico no semiárido cearense. *Extensão Rural*, 29(1), 1-35, 2023. doi: 10.5902/2318179670414.
- Prodanov, C. C.; Freitas, E. C. *Metodologia do trabalho científico: métodos e técnicas da pesquisa e do trabalho acadêmico*. Nova Hamburgo: Feevale, 2. ed., 2013.
- Queiroz, M. A.; Nascimento, C. E. S.; Silva, C. M. M. de S.; Lima, J. L. S. Fruteiras nativas do Semiárido do Nordeste brasileiro: algumas reflexões sobre seus recursos genéticos. In: *Anais do Simpósio Nacional de Recursos Genéticos de Frutíferas Nativas, 1992*, Cruz das Almas, BA: EMBRAPA-CNPMP, 1993.
- Riegelhaupt, E. M.; Pareyn, F. G. C. A questão energética. In: Gariglio, M. A. *et al.* (Orgs.). *Uso sustentável e conservação dos recursos florestais da caatinga*. Brasília: Serviço Florestal Brasileiro, 2010. p. 65-75.

- Rosset, P.; Barbosa, P. L. Territorialização da agroecologia na Via Campesina. *Boletim da Sociedade Brasileira de Economia Ecológica*, 39, 46-50, 2019. Disponível em: < <http://ecoeco.org.br/wp-content/uploads/2019/07/ECOECO-BOLETIM-V3-0507-1.pdf> > Acesso em: ago. 2023.
- Sampaio, E. V. S. B.; Gamarra-Rojas, C. F. L. Uso das plantas em Pernambuco. In: Tabarelli, M.; Silva, J. M. C. (Orgs.) *Diagnóstico da biodiversidade de Pernambuco*. Recife: SECTMA, Ed. Massangana, p.633-660. 2002.
- Sampaio, Y.; Sampaio, E. V. S. B.; Souza, H. R. Agricultura irrigada no Pólo Petrolina-Juazeiro. Impactos dos investimentos públicos e privados. In: Sampaio, E. V. S. B.; Sampaio, Y. (Orgs.) *Ensaio sobre a economia da agricultura irrigada*. Fortaleza: BNB, 2004. p. 27-186.
- Scherer-Warren, I. O que há de novo nos movimentos sociais no campo? *Redes de movimentos sociais*. São Paulo: Loyola, p. 65-77, 1993.
- Schultz, T.W. *A transformação da agricultura tradicional*. Rio de Janeiro: Zahar Eds. 1965.
- Sevilla Guzmán, E.; Alonso Mielgo, A. Para una teoría etnoecológica centroperiferia desde la Agroecología. In: *Congreso de la Sociedad Española de Agricultura Ecológica*, I. Toledo, septiembre de 1994.
- Sevilla Guzmán, E. *De la sociología rural a la agroecología*. Barcelona: Icaria, 2006.
- Silva, J. X. A agricultura no Nordeste e Meio-Norte. In: Hereda, M. G. C.; Domingues, A. J. P. (Orgs.). *Geografia do Brasil*. Grandes regiões Meio-Norte e Nordeste. Rio de Janeiro: IBGE, 1962. p. 251-272.
- Silva, R. M. A. Entre o combate à seca e a convivência com o Semiárido: políticas públicas e transição paradigmática. *Revista Econômica do Nordeste*, 38(3), 466-485, 2007.
- Silva, R. M. A. Conhecimento, economia e política: bases da sustentabilidade do desenvolvimento no Semiárido brasileiro. In: Batista Filho, M.; Miglioli, T. C. (Orgs.) *Viabilização do semiárido do nordeste: um enfoque multidisciplinar*. Recife: LICEU, 2010. p. 104-122.
- Silva, Y. L.; Gamarra-Rojas, G.; Fernandes, F. E. P. *et al.* A produção animal na economia da agricultura familiar: estudo de caso no semiárido brasileiro. *Cadernos de Ciência & Tecnologia*, 35(1), 53-74, 2018. doi: 10.35977/0104-1096.cct2018.v35.26314
- Silva, Y. L.; Rodrigues, T. M. M.; Rodrigues, M. E. *et al.* Estratégias de manejo pecuário na caatinga: o caso de agricultores assistidos pelo projeto Sustentare na comunidade Sítio Areias, Sobral, CE. *Cadernos de Ciência & Tecnologia*, 37(2), 1-20, 2020. doi: 10.35977/0104-1096.cct2020.v37.26661
- Stella, A.; Kageyama, P. Y.; Nodari, R. Políticas públicas para a agrobiodiversidade. In: MMA/SBF - Ministério do Meio Ambiente/Secretaria de Biodiversidade e Florestas. *Agrobiodiversidade e diversidade cultural*. Brasília: MMA/SBF, 2006. p. 43-58. ISBN 85-87166-90-5
- Veirano, L. C. Traços gerais da ocupação agrícola. In: Hereda, M. G. C.; Domingues, A. J. P. (Orgs.). *Geografia do Brasil*. Grandes regiões Meio-Norte e Nordeste. Rio de Janeiro: IBGE, 1962. p. 273-327.
- Velloso, A. L.; Sampaio, E. V. S. B.; Pareyn, F. G. C. *Ecorregiões propostas para o bioma Caatinga*. Recife: APNE; TNC do Brasil, 2002.
- Wanderley, M. N. B. Capital e propriedade fundiária na agricultura brasileira. In: *O mundo rural como espaço de vida*. Reflexões sobre a propriedade da terra, agricultura familiar e ruralidades. Porto Alegre: Editora da UFRGS, 2009. p. 25-43.
- Wezel, A.; Bellon, S.; Doré, T. *et al.* Agroecology as a science, a movement and a practice. A review. *Sustainable Agriculture*, 29, 503-515, 2009. doi: 10.1007/978-94-007-0394-0_3

