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SOIL SECURITY IN FAMILY AGROECOSYSTEMS IN EASTERN AMAZONIA: METHODOLOGICAL PROPOSITION

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ABSTRACT

In the Amazon region, family farmers face a crisis in the traditional management and fertility management systems of the natural environment, based on the technical system of slash and burn, questioning the sustainability of agroecosystems. To face these challenges, changes in agricultural practices in local production systems are observed, especially with the adoption of agroforestry systems. The objective was to analyze the adoption of an integral and systemic methodology for assessing soil security in the Eastern Amazon. The methodology adopted involved interviews with family farmers, diagnosis of production systems, and visual evaluation of the soil with quilombola farmers. It is concluded that the tool built is a social technology that can contribute to monitoring agroecosystems and assist in farmers' decision-making about the continuity or changes in the management practices adopted.

Keywords: Soil Management. Agroforestry Systems. Family Farming. Sustainable development. State of Pará.

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INTRODUCTION

In the face of climate change problems, the sustainability of ways of doing agriculture has been questioned by scientists, politicians, ecological movements, and other social actors. This is because the hegemonic model of agricultural production is premised on the production of *commodities* based on the use of synthetic fertilizers, pesticides, agricultural mechanization, and monocultures. This model breaks with natural cycles and ecological processes, generating a disconnection between agriculture and nature. And, it has contributed to problems such as environmental degradation, socio-territorial conflicts, and food and nutrition insecurity. (ALTIERI, 2012; BARRIOS et al., 2020; GLIESSMAN; FRIEDMANN; HOWARD, 2019; TITTONELL et al., 2020) (CORTES et al., 2020)

Of the land used for agricultural activity in South America, 14% is degraded according to the United Nations Environment Program (UNDP), through the Global Assessment of Soil Degradation (GLSOD). Degradation threatens land fertility, water quality, soil functionality, and ecological balance in general. The main factors that contribute to soil degradation are: deforestation or removal of natural vegetation; overgrazing; insufficient or excessive use of fertilizers; use of low quality and/or excess irrigation water; inappropriate use of agricultural machinery; and industrial activities, among others. The problem is exacerbated when one considers that the soil regeneration process is slow, it is estimated that it takes about 500 years for a layer of soil to form. (BRIDGES; OLDEMAN, 1999) (BRADY; WEIL, 2013)

In Brazil, data from the Ministry of the Environment estimate 140 million hectares of degraded land. The Amazon is one of the main Brazilian biomes impacted by the advance of deforestation for agricultural and mineral activities. In 2021, the Deforestation Alert System of the Institute of Man and the Environment of the Amazon recorded that 10,362 km² of native forest were destroyed. Compared to the year 2020, which was already registering a high, the devastation was 29% higher. (SAUER, 2024) (MESSIAS et al., 2021)

Given this scenario, it is necessary to reflect on the forms of agriculture practiced and seek the development of sustainable agroecosystems. Soils play a central role in this process, since good quality soil has a direct relationship with healthy plants and, consequently, with healthy people. Thus, it is understood that soil quality can be the ability of a given soil in natural or agricultural ecosystems to perform functions related to plant productivity, maintenance of biodiversity, conservation of environmental quality, promotion of plant and animal health, and the sustenance of human habitation. (PRIMAVESI, 2008) (DORAN; PARKIN, 1994; KARLEN et al., 1997)

The assessment of soil quality can be understood as an important indicator of the sustainability of agroecosystems. However, they argue that thinking about sustainable development requires broadening the concept of soil quality. Therefore, he proposes the notion of soil security that allows an integral and systemic view of soil as a global resource essential to sustainable development. (CASALINHO et al., 2007) McCartney et al. (2014)

Given such reflections, this article is premised on the premise that soil management practices are central to the construction of sustainable agroecosystems because they have a direct impact on soil security. Therefore, it is essential to know such practices, as well as the factors that condition them to encourage the continuity or change of the management systems adopted by farmers. In this sense, the objective of this article is to analyze the adoption of a comprehensive and systemic methodology for assessing soil security in the Eastern Amazon.

THEORETICAL FOUNDATION

Studies on soil quality have intensified since the 1990s, with emphasis on the publication of works by and, in the search for a broader view of ecosystems. According to Doran and Parkin (1994) Karlen et al. (1997) Araújo et al. (2012) , soil quality depends on the extent to which the soil will function for the benefit of society, based on its natural composition, considering the strong relationship with human intervention practices. Soil with good quality can recycle nutrients, retain water, and maintain an environment favorable to the development of life. (KUNDE et al., 2020)

Soil quality is studied in three lines of analysis: 1) soil attributes as indicators of soil quality; 2) centrality in soil organic matter as the main indicator of soil quality; 3) systemic approach to soil quality that seeks to encompass the complexity of soils and their functions, where it considers it more important to understand how soil quality is obtained and maintained than to measure it (). VEZZANI; MIELNICZUK, 2009

Beginning in the 2000s, soil quality researchers began to use the term soil health more regularly to refer to soil as a living system. The U.S. Department of Agriculture (USDA) defines soil health as "the soil's ongoing ability to function as a vital living ecosystem that supports plants, animals, and humans." (LEHMANN et al., 2020;

TORRES et al., 2022) [4] In this approach, the soil resource is considered a natural, biological, historical, and cultural heritage.(TORRES et al., 2022)

Although the literature observes the use of the concept of soil health as a synonym for soil quality, there are differences, because the first includes as a function of the soil "broader sustainability objectives that include human and planetary health", while the second "generally focuses on ecosystem services concerning human interests, especially agricultural production". (LEHMANN et al., 2020)

The soil security approach was developed to relate sustainable development with the maintenance and improvement of global soil resources to produce food, fiber, and fresh water, contribute to energy sustainability, climate regulation, maintain biodiversity, and overall ecosystem protection. The term safety denotes the absence of risks, damages, dangers, and uncertainties. Thus, soil safety can be defined as the absence of risks of loss of a function or a group of soil functions. (McBratney et al., 2012) (CEDDIA et al., 2017)

Soil security is based on the evaluation of five dimensions: 1) capacity (natural potential of the soil to favor plant growth, soil suitability, store carbon, water and maintain biodiversity); 2) condition (current soil status, management and use will reflect on soil quality and health); 3) capital (valorization of soil ecosystem services); 4) connectivity (reconnecting people with the land) and; 5) codification (elaboration of policies for the protection and conservation of the soil). (McBratney et al., 2014)

While, soil quality and health measure soil condition, soil security is proposed more broadly to occupy the same position as other security (food, water, and energy), as a human right in a political context, encompassing socioeconomic, cultural, and legal aspects of soil management. In this sense, the discussion on soil security allows the understanding of soil as a common good, similar to what happens in debates about water and air. (LEHMANN et al., 2020) (McBratney et al., 2014) (LEHMANN et al., 2020)

Central questions here to advance the applicability of the concept of soil safety are: how to integrate the five dimensions? How to integrate concepts and methods from the human sciences with the agricultural and natural sciences? To this end, they propose, as a key integrator, a sixth dimension. Ceddia et al. (2017) and Grunwald et al. (2017) *Cognizance* — it describes individual and collective knowledge, consciousness, and perception, interacting with the system, soil, ecosystem, and other elements that makeup soil security. For practical purposes, a *Meta Soil Model* based on integral theory (applied to

[4] More information at https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/

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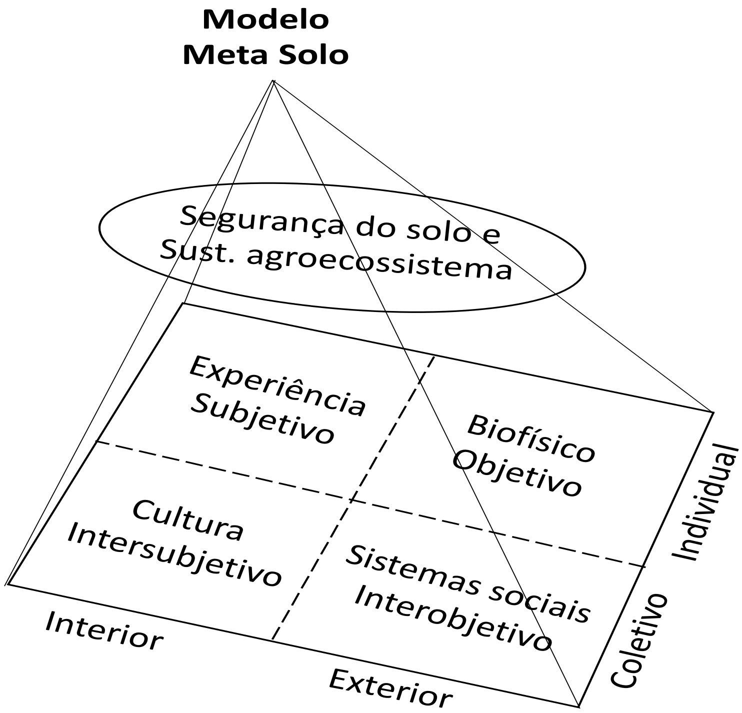
ecology) is suggested, which is based on the combination of perceptions from various fields of knowledge, such as human, natural, and other sciences.

Integral theory presupposes that there are at least four irreducible perspectives or quadrants, namely: subjective, intersubjective, objective, and interobjective. These must be evaluated when one wants to understand reality in a complex way. The quadrants allow us to observe a given question of reality holistically, based on two distinctions: 1) interior and exterior perspective and; 2) individual and collective perspective. (ESBJÖRN-HARGENS; ZIMMERMAN, 2009)

Figure 1 - Integral map, derived from integral theory, represents the four quadrants, which provide all perspectives to visualize soil security and agroecosystem sustainability.



Source: adapted. (CEDDIA et al., 2017)

The upper left quadrant, comprises the individual experience of the farmer about his agroecosystem and management practices, that is, the perception; the lower left quadrant comprises the collective experience, values, and beliefs of the community; the upper right quadrant comprises the functions, attributes, and management of the soil; The lower right quadrant comprises the economic, social, political, and legal systems.

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METHODOLOGICAL ASPECTS

This research has a theoretical-analytical contribution to the systemic approach applied to the study of family agroecosystems. It starts from a bottom-up approach, based on the observation of farmers' practices related to soil management, the understanding of the logic of social reproduction and the consequences on the sustainability of agroecosystems. It seeks to contemplate the experiences of farmers in an interdisciplinary and complex perspective. The theoretical-analytical premise here was to value the experiences of farmers, through the integration of scientific knowledge and traditional knowledge and practices, as well as to evaluate the limits and potentialities of these experiences. (PINHEIRO, 2000) (MORIN, 2005) (ZANELLI et al., 2021)

In this sense, the combination of methods and techniques of quantitative and qualitative character was articulated, to evaluate the management practices and apprehend the processes of changes inherent to the production systems, the perceptions of the peasants involved in the research, as well as the impacts of the management carried out on soil security, having as key indicators, the invertebrate macrofauna of the soil, soil structure and local indicators (ethnoindicators) of soil health. (CASALINHO; LIMA, 2018)

The analytical framework of the research that guided the data collection was guided by the integral theory as shown in Figure 2. In the interior-individual quadrant, it corresponds to the collection of data from the farmers' perception of the soil and the sustainability of agroecosystems. In the interior-collective quadrant, it corresponds to the survey of data on the collective perception of the community involved (survey of ethnoindicators). In the outer-individual quadrant corresponds to the survey of analytical data (chemical characterization of soil texture, evaluation of edaphic fauna, diagnosis of soil structure). The outer-collective quadrant corresponds to data related to social and agrarian systems in the territory studied.

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Figure 2 - Synthesis of the analytical framework of research on soil health in the Eastern Amazon.

	Interior	Exterior
Individual	Experiência Percepção sobre o solo e a sustentabilidade dos agroecossistemas Realização de entrevistas com agricultores Objetivos i e ii	Biofísico/Agroecossistema Caracterização química do solo Macrofauna invertebrada do solo como indicador da saúde do solo Índice da Qualidade Estrutural do Solo Objetivos i, ii
Coletivo	Cultural Reflexões coletivas sobre as práticas agrícolas e seus possíveis impactos sobre a saúde do solo e a sustentabilidade dos agroecossistemas Oficinas participativas para caracterização agroambiental das comunidades (BARRIOS et. al. 2011; CARMO et. al. 2018) Objetivos i, e iii	Sistemas sociais/Sistema agrário Análise de sistema de produção Aplicação de questionários com informantes-chave e agricultores da comunidade Objetivos i e iii

Source: Prepared by the authors (2024). Source: Adapted from Ceddia et al., (2017) and Grunwald et al., (2017).

There is no doubt about the importance of soils for the healthy cultivation of plants, food and water security/sovereignty, energy sustainability, climate stability, biodiversity protection, and ecosystem services. However, a conception of the soil as a substrate to which synthetic fertilizers must be added to nourish the plants still predominates. Therefore, it is necessary to reframe this perception of soil, recognizing it in research, teaching, and public policy agendas, as an integral part of humanity's current challenges to achieve sustainable development. (CARDOSO et al., 2018)

In this sense, by seeking to understand the evolution of soil management practices and their impacts on the sustainability of agroecosystems, it was intended to generate knowledge and provoke reflections that point out ways to ensure soil health in the community studied.

This research also adopts the agroecological focus by privileging the dialogue of knowledge for the analysis of agroecosystems. A complex science with political and socio-cultural dimensions, which recognizes and respects different knowledge. In this way, it allows the connection between integral theory and ethnopedology, by placing in the key of analysis the perception of those who manage the soils, in addition to promoting integration with knowledge obtained by quantitative analyses.

Ethnopedology studies generally approach soil from four perspectives: 1) soil classification based on local knowledge; 2) comparison of local rankings with academic rankings; 3) analysis of the evaluation of local soils descriptively; and 4) evaluation of soil management practices seeking to explain the meanings of know-how from the integration of the local knowledge system (Corpus), local management system (Praxis) and system of local beliefs and symbols (Kosmos). The latter was used in this study because it allows the association of perceptions, knowledge, and management practices to apprehend, in a complex perspective, the observed phenomena (). In addition to allowing integration with the other theoretical-methodological contributions of the integral theory. (BARRERA-BASSOLS; ZINCK, 2003) TOLEDO; BARRERA-BASSOLS, 2015; CARMO et al., 2018

The incorporation of soil security into the agroecological approach can mean advances in the production of knowledge in the field of agroecology. This is because agroecology and soil health have several approaches that can be considered close, such as the adoption of ecological principles, sustainable agriculture, traditional systems, climate change, ecological economics, and social and political transformation. Sustainable agroecosystems presuppose ecological soil management with practices such as maintenance of vegetation cover on the soil, crop rotation, and diversification. Such practices can prevent the main risks of soil degradation, compaction, and erosion.

FAMILY AGROECOSYSTEMS IN THE EASTERN AMAZON

In the Eastern Amazon, two major environments stand out and mark the ways of life of the peasants: the terra firme and the várzeas. In these environments, peasants have developed, over time, diversified agroecosystems with a combination of crops (annual and perennial), livestock (small and large animals), extractives (socio-biodiversity products), artisanal fishing (for those who have access to the river) and fish farming in tanks. The production systems developed by these farmers in their territories are also marked by political, social, and cultural processes that condition a wide diversity of forms of production and the relationship of men and women with nature.

In the areas of dry land, the technical system of cutting and burning (based on the use of fire) is still the main practice of area preparation and management of the fertility of the natural environment, which has proven to be a crisis in the local production systems. The crisis in the technical slash-and-burn system is aggravated as there is pressure on the preservation of biomes that are important for climate balance, such as the Amazon.

Scholars of peasant production units in the state of Pará, as reported in their works, that the crisis in the burning cutting system is due to the reduction of fallow time and, reduction of cultivation areas, intensified by the demographic increase, causing greater pressure on forest area. In addition, the expansion of agro-industrial sectors in the region, such as oil palm cultivation in the Northeast of Pará, promotes the reduction of areas for the cultivation of food species, as they observed. Conceição (2002) Hurtienne (2005) Silva and Navegantes-Alves (2017)

The consequences of this crisis have been the loss of soil fertility, increased soil erosion processes, loss of biodiversity, abandonment of areas by farmers, and migration to urban centers in search of opportunities or to become rural employees in monoculture areas or farms. (SÁ; KANASHIRO; LEMOS, 2014)

The use of fire as an area preparation technique impacts the physical, chemical, and biological properties of the soil. Fire eliminates organic material from the surface layer of the soil, increasing water runoff and, consequently, causing erosion. As a consequence of these changes, there is a reduction in biological activity. (OLIVEIRA et al., 2022) (REGO; KATO, 2018)

In a study carried out by, family production systems in Cametá (Northeast of Pará), it was identified that the average cassava production was 12 t. Alves and Modesto-Jr. (2014) $^{ha-1}$, a low result, considering that there are communities that achieve a yield of 26 t. $^{ha-1}$ in the state of Pará. Furthermore, these authors argue that the main factors that influence the low yield of cassava production is soil degradation, leading, obviously, to the loss of soil fertility.

Given this, it is evident that soil security in this region becomes an urgent issue for research agendas and local development actions, to build ways to improve and maintain soil functions, as well as the sustainability of agroecosystems.

In this sense, it is possible to observe initiatives specific to the organization of farmers through the implementation of agroforestry systems; as well as technical and productive interventions through government programs such as the National Biodiesel Production Program (PNPB) for the recovery of degraded areas in the Legal Amazon through the implementation of oil palm trees and; actions of NGOs such as the network of multiplier farmers program of the Pará Association for the Support of Needy Communities (APACC) based on the adoption of agroforestry systems, organic cultivation of vegetables, psycho culture and beekeeping. (REGO; KATO, 2018) (RITTER; RED-HAIRED; ALMEIDA, 2017)

FERTILITY MANAGEMENT IN FAMILY AGROECOSYSTEMS

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The notion of fertility management of the natural environment differs from the concept of soil fertility established in soil science. This is because this notion goes beyond the idea of fertility associated mainly with the mineral elements of the soil. The fertility of the natural environment is a product of nature transformed by the practice of peasants. A certain type of soil or vegetation that for some peasants would not be of sufficient quality for permanent crops, for others it is possible to cultivate them through their practices. (VEIGA; ALBALADEJO, 2002) (CARMO; SILVA, 2020; ROCK; ALMEIDA, 2013)

Thus, fertility management is about the productive capacity of the environment as a constructed process, between nature and society and not only nature, as a given and immutable object. Therefore, the slash-and-burn system can be understood as a fertility management practice in the natural environment. (TAVARES; VEIGA, 2006)

Figure 3 shows an area used by the slash-and-burn system, in the image (A) a capoeira at the "swidden point", in image (B) the area after the felling and burning of vegetation and in image (C) the plot implanted with cassava species. Slash-and-burn agriculture is a technical system for managing the fertility of the natural environment that has been practiced for thousands of years in the forested areas of the planet, especially in tropical regions. This cultivation technique can be defined as a resource management strategy, where the cultivated plots are rotated, in time and space, aiming to exploit the energy and nutritive capital of the natural soil-vegetation complex of the forest. (PEDROSO JR. et al., 2008) (VIEIRA et al., 2014)

Figure 3 - Area used in the slash-and-burn system in the Eastern Amazon.

Source: Authors (2023). (A) Capoeira representing the ideal state for swiddenness — "swidden point"; (B) area after burning, ready for planting plant species; (C) area implanted with cassava cultivation.

As already argued, the slash-and-burn system is in crisis in the areas of older colonization of the Amazon due to the demographic increase without a corresponding increase in area that allows maintaining fallow time. The shortening of fallow reduces the time for natural regeneration of biomass, increasing the incidence of invasive weeds and, as a consequence, the greater demand for labor and lower productivity per area. (MARTINS et al., 2014)

CONCLUSION

The participatory research with farmers showed that agricultural practices have undergone several changes due to factors both internal to agroecosystems and external factors such as pressure from agro-industrial companies, the opening of roads, and the policy of recognition of traditional territories.

The slash-and-burn system is in decline, families over time have specialized in cassava production for flour making, and they face challenges to maintain such a cultivation system. However, it was possible to observe that agricultural practices change with the adoption of agroforestry systems. These systems can contribute to the sustainability of agroecosystems, as observed in this study.

Farmers have adopted the fireless swidden and agroforestry systems as the main strategy to face the crisis in the slash-and-burn system. Thus, there is a trend towards a land use dynamic based on SAF.

The soil safety assessment showed that the new management practices adopted by farmers maintain soil health. The indicators adopted proved to be efficient for the evaluation of soil health and can be replicated in realities similar to this study. Thus, as the methodology of co-construction of knowledge about soil health, this tool can be useful for rural extension and public policies to promote the recovery of degraded areas.

It was evident that some results were only possible due to the long process of approaching the community and building a relationship of trust. Thus, programs that intend to carry out actions similar to this study need to consider the need for more lasting actions. These approximations need to value local knowledge, as well as build concrete actions based on the dialogue of knowledge and the effective participation of the community in the idealization and materialization of the proposals.

The evaluation of crop productivity in agroforestry systems is an important indicator that needs to be considered. Thus, for the continuity of the study initiated, it is necessary to think of methodologies to evaluate productivity and, to make a complete analysis of the sustainability of these agroecosystems, it is also necessary to evaluate the economic aspects.

The construction of local soil health indicators generated a soil health monitoring system based on the knowledge of quilombola farmers. The participatory tool is a social technology that the community can mobilize to monitor agroecosystems and make decisions about the continuity or changes in the management practices adopted.

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REFERENCES

1. Altieri, M. (2012). Agroecology: scientific bases for sustainable agriculture (3rd ed.). São Paulo: Expressão Popular.

2. Alves, R. N. B., & Modesto-Jr., M. de S. (2014). Ecological based agriculture of gardens without fire in capoeira vegetation for cassava production in Cametá, Pará. Documents / Embrapa Eastern Amazon, (407), 1–22.

3. Araújo, E. A. de, et al. (2012). Soil quality: concepts, indicators and evaluation. Applied Research & Agrotechnology, 5(1).

4. Barrera-Bassols, N., & Zinck, J. A. (2003). Ethnopedology: A worldwide view on the soil knowledge of local people. Geoderma, 111(3–4), 171–195.

5. Barrios, E., et al. (2020). The 10 Elements of Agroecology: enabling transitions towards sustainable agriculture and food systems through visual narratives. Ecosystems and People, 16(1), 230–247.

6. Brady, N. C., & Weil, R. R. (2013). Elements of nature and properties of soils (3rd ed.). Porto Alegre: Bookman.

7. Bridges, E. M., & Oldman, L. R. (1999). Global assessment of human-induced soil degradation. Arid Soil Research and Rehabilitation, 13(4), 319–325.

8. Cardoso, I. M., & Fávero, C. (Eds.). (2018). Resignifying our perceptions about the soil: an essential attitude to manage sustainable agroecosystems. In Soils and Agroecology (pp. 33–60). Brasília: Embrapa.

9. Carmo, P. S. R., & Silva, E. M. (2020). Management of the fertility of the natural environment carried out by family farmers in Cametá, Pará. Cadernos de Agroecologia, 15(2), 1–6.

10. Carmo, V. A. do, et al. (2018). Ethnopedology: seeking the look of those who tomorrow the earth. In I. M. Cardoso & C. Fávero (Eds.), Soils and Agroecology (pp. 159–200). Brasília: Embrapa.

11. Casalinho, H. D., et al. (2007). Soil quality as an indicator of sustainability of agroecosystems. Revista Brasileira de Agrociência, 13(2), 195–203.

12. Casalinho, H. D., & Lima, A. C. R. (2018). Integration of knowledge in the construction of a methodology for soil quality assessment. In I. M. Cardoso & C. Fávero (Eds.), Soils and agroecology (pp. 201–236). Brasília: Embrapa.

13. Ceddia, M. B., et al. (2017). Applying the Meta Soil Model: The complexities of soil and water security in a permanent protection area in Brazil. In D. J. Field, C. L. S. Morgan, & A. B. McBratney (Eds.), Global Soil Security (pp. 331–340). Cham: Springer International Publishing.

14. Conceição, M. F. C. (2002). Social reproduction of family farming: a new challenge for agrarian society in the Northeast of Pará. In J. Hébette, S. B. Magalhães, & M. C. Maneschy (Eds.), At sea, in the rivers, and on the border: faces of the peasantry in Pará (pp. 133–171). Belém: ed.ufpa.

15. Cortes, J. P. S. de, et al. (2020). What are the perspectives of family farming in the context of agribusiness expansion? Participatory zoning with community representatives from Planalto Santareno. Confins, 45.

16. Doran, J. W., & Parkin, T. B. (1994). Defining and assessing soil quality. In J. W. Doran et al. (Eds.), Defining soil quality for a sustainable environment (35th ed., pp. 3–21). Madison: Soil Science Society of America.

17. Esbjörn-Hargens, S., & Zimmerman, M. E. (2009). An overview of integral ecology: a comprehensive approach to today's complex planetary issues. Integral Institute-Resource Paper, 2, 1–14.

18. Gliessman, S., Friedmann, H., & Howard, P. H. (2019). Agroecology and food sovereignty. IDS Bulletin, 50(2).

19. Grunwald, S., et al. (2017). The Meta Soil Model: An integrative multi-model framework for soil security. In D. J. Field, C. L. S. Morgan, & A. B. McBratney (Eds.), Global Soil Security (pp. 305–317). Cham: Springer International Publishing.

20. Hurtienne, T. P. (2005). Family farming and sustainable rural development in the Amazon. Novos Cadernos NAEA, 8(1), 19–71.

21. Karlen, D. L., et al. (1997). Soil quality: a concept, definition, and framework for evaluation. Soil Science Society of America Journal, 61, 4–10.

22. Kunde, R. J., et al. (2020). Physical, chemical and biological quality of a Litholic Neosol under crop-livestock integration in the Pampa Biome. Research, Society and Development, 9(10), 1–20.

23. Lehmann, J., et al. (2020). The concept and prospects of soil health. Nature Reviews Earth and Environment, 1(10), 544–553.

24. Martins, P. F. da S., et al. (2014). Limitations to the agricultural use of uplands in the Amazon and transformation of the production systems of family farmers in the Lower Tocantins Territory. Family Farming: Research, Training and Development, 10, 67.

25. McBratney, A., et al. (2012). Frameworks for digital soil assessment. In B. Minasny, B. P. Malone, & A. McBratney (Eds.), Digital soil assessments and beyond. London: Taylor & Francis Group.

26. McBratney, A., Field, D. J., & Koch, A. (2014a). The dimensions of soil security. Geoderma, 213, 203–213.

27. Messias, C. G., et al. (2021). Analysis of deforestation rates and their associated factors in the Brazilian Legal Amazon in the last three decades. Raega - O Espaço Geográfico em Analysis, 52, 18.

28. Morin, E. (2005). Introduction to complex thinking. Porto Alegre: Sulina.

29. Oliveira, R. L. L. de, et al. (2022). Management practices affect soil carbon and physical quality in oil palm agroforestry systems in the Amazon. Journal of Soil Science and Plant Nutrition, 22(4), 4653–4668.

30. Pedroso Jr., N. N., Murrieta, R. S. S., & Adams, C. (2008). Slash-and-burn agriculture: a system in transformation. Boletim do Museu Paraense Emílio Goeldi. Ciências Humanas, 3(2), 153–174.

31. Pinheiro, S. L. G. (2000). The systemic approach and sustainable rural development: An opportunity to change from the hard-systems approach to experiments with soft-systems. Agroecology and Sustainable Rural Development, 1(2), 27–37.

32. Primavesi, A. M. (2008). Agroecology and soil management. Revista Agriculturas, 5(3), 7–10.

33. Rego, A. K. C., & Kato, O. R. (2018a). Slash-and-burn agriculture and agroecological alternatives in the Amazon. Novos Cadernos NAEA, 20(3), 203–224.

34. Rego, A. K. C., & Kato, O. R. (2018b). Slash-and-burn agriculture and agroecological alternatives in the Amazon. Novos Cadernos NAEA, 20(3), 203–224.

35. Ritter, L. H., Ruivo, M. de L. P., & Almeida, A. S. de. (2017). Effects of technical-productive interventions for the sustainability of land use in family agroecosystems in the territory of Baixo Tocantins, Pará. In S. S. Vasconcelos, M. de L. P. Ruivo, & A. M. M. de Lima (Eds.), Amazônia em tempo: impacto do uso da terra em diferentes scales (pp. 133–163). Belém: UFPA and Museu Paraense Emílio Goeldi.

36. Rocha, C. G. S., & Almeida, J. P. de. (2013). Local knowledge and practices of fertility management in the natural environment among family farmers in the Microregion of Altamira, Pará, Brazil. Amazônica: Revista de Antropologia, 5(3), 892–908.

37. Sá, T. D. D. A., Kanashiro, M., & Lemos, W. D. P. (2014). Interdisciplinarity and transdisciplinarity in Amazonian agricultural research: a challenge to achieve sustainability. Revista Agroecossistemas.

38. Sauer, S. (2024). Eco-Agrarian Question: agrarian extractivism, climate change and deforestation in Brazil. REVISTA NERA, 27(2).

39. Silva, E. M., & Navegantes-Alves, L. D. F. (2017). Transformations in family production systems in the face of the implementation of oil palm cultivation in the Eastern Amazon. Development and Environment, 40, 345–364.

Revista ARACÊ
ISSN: 2358-2472

40. Tavares, F. B., & Veiga, I. (2006). Diversity of knowledge and practices related to pasture management in a locality on the agrarian frontier of the Eastern Amazon. Amazonia: Ci. & Desenv., 2(1), 111–126.

41. Tittonell, P., et al. (2020). Agroecology in large scale farming—A research agenda. Frontiers in Sustainable Food Systems, 4.

42. Toledo, V. M., & Barrera-Bassols, N. (2015). Biocultural memory: the ecological importance of traditional wisdom (1st ed.). São Paulo: Expressão Popular.

43. Torres, L. A., et al. (2022). Soil health. In L. A. Torres & S. K. Campos (Eds.), Soil Science Megatrends 2030 (pp. 183–241). Brasília: Embrapa.

44. Veiga, I., & Albaladejo, C. (2002). Management of soil fertility in a locality in the Eastern Amazon: the formalization of farmers' points of view aiming at a dialogue between farmers and agronomists. Family Farming: Research, Training and Development, 1(3), 109–137.

45. Vezzani, F. M., & Mielniczuk, J. (2009). A view on soil quality. Brazilian Journal of Soil Science, 33(4), 743–755.

46. Vieira, I. C. G., Santos Jr., R. A. O., & Toledo, P. M. (2014). Productive dynamics, transformations in land use and sustainability in the Amazon. In N. Silfert et al. (Eds.), A territorial look at the development of the Amazon (pp. 370–395). Rio de Janeiro: BNDES.

47. Zanelli, F. V., Barbosa, W. A., & Cardoso, I. M. (2021). Emancipatory methodologies. In A. P. Dias et al. (Eds.), Dicionário de agroecologia e educação (1st ed., pp. 489–500). São Paulo: Expressão Popular.