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ABSTRACT

The study aims to characterize and analyze the environmental and economic sustainability of the production systems in the community of Novo Horizonte, located at the headwater of Lake Janauacá in the state of Amazonas. The theoretical and methodological framework used was based on the principles of Agricultural Systems Analysis and Diagnosis (ADSA). Field research was conducted during August 2023, where 10 producers were interviewed and information was collected regarding the history of local agriculture, as well as economic and agronomic aspects of the production systems developed by the farmers. The history of local agriculture can be divided into three distinct periods. Currently, agriculture is undergoing a phase of strong expansion, due to the increase in the prices of cassava flour, the main agricultural product of the region. In this context, a specific and principal type of farmer stands out, known as "Family Farmer - Complete Cycle Cassava House" (AF-CFCC), whose social reproduction is ensured by the production and processing of cassava. In addition, there is an intense process of experimentation with new production systems among farmers, whether through the diversification of production or by seeking to abandon the slash-and-burn system in favor of mechanized planting and the use of chemical inputs in cassava production. These processes have a direct relationship with the perspectives for sustainable development of local agriculture.

Keywords: Agricultural Systems. Family Farming. Cassava. Cassava Flour.

RESUMO

O estudo tem como objetivo caracterizar e analisar a sustentabilidade ambiental e econômica dos sistemas de produção da comunidade Novo Horizonte, localizada na cabeceira do Lago do Janauacá, no estado do Amazonas. O referencial teórico-metodológico utilizado baseou-se nos princípios da Análise-Diagnóstico de Sistemas Agrários (ADSA). A pesquisa de campo foi realizada durante o mês de agosto de 2023, na qual foram entrevistados 10 produtores e coletadas informações a respeito da história da agricultura local, bem como sobre aspectos econômicos e agronômicos dos sistemas de produção desenvolvidos pelos agricultores. A história da agricultura local pode ser subdividida em três períodos distintos. De modo que atualmente, a agricultura passa por um momento de forte expansão, devido ao aumento dos preços da farinha de mandioca, o principal produto agrícola da região. Nesse contexto, destaca-se um tipo específico e principal de agricultor denominado "Agricultor Familiar - Casa de Farinha Ciclo Completo" (AF-CFCC), cuja reprodução social é assegurada pela produção e processamento da mandioca. Além deste, observa-se um intenso processo de experimentação em novos sistemas de produção pelos agricultores, seja por meio da diversificação da produção, seja pela busca do abandono do sistema de derrubada e queimada, em favor do plantio mecanizado e do uso de insumos químicos na produção de mandioca. Esses processos têm relação direta com as perspectivas de desenvolvimento sustentável da agricultura local.

Palavras-chave: Sistemas Agrários. Agricultura Familiar. Mandioca. Farinha de mandioca.

INTRODUCTION

The most recent studies on climate change indicate that the global increase in temperature has been progressively intensifying over the last few decades. According to the Intergovernmental Panel on Climate Change, when the increase in global surface temperature over the last 2000 years is analyzed, it is clear that in the last 50 years the temperature has increased faster than in any other 50-year period (IPCC, 2023). According to the Synthesis Report on Climate Change, "human activities, mainly through greenhouse gas emissions, have unequivocally caused global warming, with global surface temperatures reaching a value 1.1°C higher between 2011-2020 than in the 1850-1900 period" (IPCC, 2023, p. 20).

Among the factors that contribute to this scenario, the energy matrix, the way in which land is exploited, lifestyles, and production and consumption patterns of societies deserve mention. In this context, the Brazilian Legal Amazon plays a prominent role in national and international terms, as it occupies 58.93% of the national territory (IBGE, 2022) and is considered the largest tropical forest in the world, which means that changes in the use of local land and vegetation have a high potential impact on the global climate (Prevedello et al., 2019), either by contributing to mitigating the effects of climate change or by catalyzing the process of global warming.

In recent decades, concerns related to agrarian and agricultural dynamics in the Brazilian Amazon have had a prominent place on research agendas, especially concerning the advancement of the agricultural frontier and the sustainability of production systems implemented in the region (Galuch; Costa, 2023; Santos; Olivera; Ignotti, 2021; Galuch; Menezes, 2020; Nóbrega, 2014). The undesirable externalities of disorderly occupation and unsustainable exploitation of natural resources highlight the need to investigate the heterogeneity of production systems, especially with a view to analyzing their contributions to the social reproduction of rural families and to the construction of sustainable food production systems.

Added to this context is the fact that in the Legal Amazon, areas whose native vegetation is composed of forest must preserve at least 80% of the area as Legal Reserve (BRASIL, 2012). This means that the activities developed by local farmers must have a high potential for generating income per hectare in the remaining area, as they need to provide material conditions for generational succession in the field or, according to Mazoyer and Roudart (2010), to guarantee the social reproduction of farmers.

In addition to implementing production systems with high potential for generating income per unit of usable area, the pursuit of sustainable regional development requires that these production systems be compatible with environmental preservation, the maintenance of ecosystem services, and the mitigation of the effects of climate change. The term used by the IPCC to describe the alternatives is "sustainable agricultural intensification," which involves sustainable land management, the promotion of sustainably sourced agricultural and forestry products, agroforestry systems, community-based adaptation, and agricultural diversification (IPCC, 2021; 2023).

The concern that emerges from this discussion is how the different local production systems contribute to regional development, the concept of which refers to a social change aimed at improving the quality of life and economic progress of societies based on the environmental, social, cultural, political and economic specificities of each region (Piacenti; Lima; Eberhardt, 2016). The Agrarian Systems Diagnostic Analysis-ADSA (Mazoyer; Roudart, 2010; Dufumier, 2010) provides a multidisciplinary and systemic tool that seeks to analyze the dynamics and problems of agriculture in a given location and, from this, allows us to point out the contributions and limits of production systems for sustainable regional development.

Therefore, the present study aims to characterize and analyze the environmental and economic sustainability of the production systems of the Novo Horizonte community, located at the headwater of Lake Janauacá. For this purpose, the paper is divided into four more sections. Next, a brief characterization of the region is presented. The third section discusses the theoretical and methodological aspects of the approach used, and the fourth section presents and discusses the results. The final considerations section is the last part of the manuscript.

GENERAL CHARACTERIZATION OF AGRICULTURE IN THE LAKE JANAUACÁ REGION

Lake Janauacá is located on the right bank of the Solimões River, with water occupying the territories of the municipalities of Careiro da Várzea and Manaquiri, approximately 110 km from the city of Manaus (Figure 1). According to data from the 2022 Demographic Census, Careiro da Várzea had a population of 19,637 residents, while Manaquiri had 17,107. Compared to the 2010 Demographic Census, both municipalities lost approximately 20% of their population. In addition, both municipalities are characterized by having the majority of the population living in rural areas (IBGE, 2010, 2022). From a socioeconomic point of view, official data indicate that the region of Lake Janauacá has low human development indices, so that the HDI of Careiro da Várzea and Manaquiri are, respectively, 0.569 and 0.596 (IBGE, 2024).

Figure 1 | Location of the Novo Horizonte community, Amazonas, Brazil.

Source: Prepared by the authors.

The Janauacá Lake region is made up of two environments, in addition to the lake itself. The igarapés, watercourses that feed the lake; and the Paraná, the canal that connects it to the Solimões River. The dry lands surrounding the lake should also be mentioned, which is where the road infrastructure is located, consisting of local roads that connect the region to the BR 119 highway. Agriculture in the Lake region is strongly impacted by these geographic characteristics and hydrological dynamics. In the cultivated lands near the Solimões River, whose waters rich in sediments (the so-called "white waters" or "muddy waters") periodically bathe the floodplains located to the north of the Lake, there are systems of low tides, especially aimed at short-cycle crops, such as corn and beans, but where cassava is also produced for the production of flour. Although the natural fertilization promoted by floods facilitates the reproduction of soil fertility, the variability of the lake's hydrological cycle poses a certain risk to the flood systems.

In turn, in the southern regions of the lake, including the streams, the rainwater that bathes the forests carries only organic compounds that are poor in nutrients, which contribute little to the reproduction of fertility. This "black water" is what gives the lake and its streams their characteristic dark color. In these black water areas, slash-and-burn systems predominate, where cassava is produced mainly for the local production of flour. On the dry lands that are connected by the local roads that connect the lake to BR 119 highway, land use is characterized by beef cattle farming, developed on permanent pastures.

The three land use patterns described in the previous paragraph have a direct impact on forest cover. Thus, while floodplain and slash-and-burn systems tend to maintain a significant surface of secondary forest in rotation with cultivated plots, the systems developed along roads lead to the permanent removal of forest cover (Figure 2).

Figure 2 | Land use on the banks of BR 119 highway (A) and around the Novo Horizonte Community (B).

Source: Extracted from Google Earth (2023).

The present study was carried out in the Novo Horizonte community, Careiro Castanho - AM, and farming in the surroundings of the community is carried out through slash-and-burn systems, whose land use pattern, as previously mentioned, contrasts with that of the nearest local road, which connects the Cinturão Verde community to BR 119 highway, as can be seen in Figure 2. On the other hand, Figure 2 shows the deforested areas around the Novo Horizonte community, especially on the right bank of the stream (where the community headquarters is located), are relatively high, indicating relatively short periods of forest fallow.

THEORETICAL-METHODOLOGICAL FRAMEWORK

This research was conducted based on the theoretical and methodological principles of the Diagnostic Analysis of Agricultural Systems (ADSA), whose application allows us to understand the dynamics of production systems at different levels, from the general to the particular. The “Agrarian System” level is the most general and corresponds to the specific way of exploiting the ecosystem, resulting from profound historical transformations and large-scale geographic adaptations. In turn, the production systems level concerns the way in which the means of production are combined to exploit the ecosystem. The third level addresses the cultivation and breeding subsystems, in which plant and animal production developed internally within the production unit are analyzed. Finally, the last level deals with the technical itineraries applied to crops and livestock, which are defined as a logical succession of elementary technical operations (Mazoyer, Roudart, 2010; Dufumier, 2010; Silva Neto, 2005).

From an operational point of view, ADSA is performed according to a sequential set of steps. In the present study, these steps can be presented in three main moments, whose developments not by chance constitute the main results of this paper, namely: i) landscape reading and historical reconstruction of the local agrarian systems; ii) identification of the different types of farmers and subsequent agroeconomic analysis; iii) discussion of strategic lines of development. In the first stage, the general socio-environmental characterization of the study region was carried out through analysis of aerial images and bibliographic documents. Subsequently, an analysis of the local agrarian history was carried out, from which the main processes of social differentiation and trajectories of accumulation of means of production were reconstructed. The information was obtained from secondary sources and, mainly, through field interviews with people who followed the transformations undergone by agriculture during the last decades.

In the second stage, the production units of the headwater of Lake Janauacá were grouped into types, resulting from the analysis of the differentiation processes identified in the previous stage. This typology aims to group the agricultural production units according to the social categories of the farmers and their production systems. In this paper, the basic social categories used are family farmers (with a predominance of family labor), employer farmers (with structural dependence on hired labor). Regarding production systems, the productive activities developed by the farmers, as well as the resources available in the production units, are considered to create the typology. The information for creating the typology was obtained through interviews with farmers, who were progressively selected throughout the study, and the accumulation trajectories identified in the previous stage were the starting point.

This stage also included the technical and economic characterization of the identified production systems, including their technical itineraries, their income generation potential and their capacity for social reproduction. For this purpose, it is essential to analyze the Value Added – VA and Agricultural Income – RA of each type of farmer, as well as develop the respective global models. All calculations were performed based on a methodology established in studies that used the systemic approach (Dufumier, 2010; Silva Neto, 2015). While Value Added allows us to understand the generation and distribution of wealth for society as a whole, Agricultural Income represents the portion of this added value that is appropriated by the family members who make up the production process. This last analytical category is important for assessing the Level of Social Reproduction – NRS of farmers, given that a production unit tends to reproduce itself socially if the workers are paid for their work.

In the analysis of the technical itineraries, we sought to identify the periods where a production unit faces the greatest resource constraints (critical periods), by examining the calendars for labor and equipment use in the agricultural season, along with the monetary flows of each agricultural activity. In this paper, special attention was given to the analysis of the use of labor force, as the activities developed by farmers in the region require a considerable number of hours. Thus, a graph was created for each production system containing the time allocated to each activity in all months of the year, which allowed us to identify periods of work overload based on the contrast between the time available to the family and the labor demand of the production system.

The final stage of this research concerns the analysis of regional development prospects. For this purpose, it was necessary to identify the main problems of local agriculture and, above all, to point out strategic lines of regional development with a focus on sustainability, based on local conditions. In other words, this study is based on the environmental, social, economic and technical contexts identified in the field, to the detriment of exogenous and exclusionary projects and programs.

All field research was carried out in August 2023, in the Novo Horizonte community, located at the headwater of Lake Janauacá, in the State of Amazonas. In the end, 10 interviews were conducted, including residents, farmers and local leaders. Semi-structured interviews were developed based on guiding questions. Quantitative data were used to perform agroeconomic calculations and the qualitative data were subjected to a content analysis, which was the database and information from which this paper originated.

Finally, the selection of research participants prioritized ADSA precepts. Thus, farmers with greater local experience, able to reconstruct the history, and farmers who developed production systems that best represented the types identified were interviewed. Ethical principles were adopted in all interviews, with participants being informed about the research and only interviewed after their consent.

RESULTS AND DISCUSSION

This section is subdivided into three parts. Initially, the historical formation of the agriculture examined is discussed. Next, an analysis of the agronomic and socioeconomic characteristics of the different production systems observed is carried out. Then, the perspectives and strategic lines for the development of local agriculture are discussed.

THE HISTORICAL FORMATION OF AGRICULTURE AT THE HEADWATER OF LAKE JANAUACÁ

Based on the interviews conducted, it can be determined that the recent occupation of the territory at the headwater of Lake Janauacá occurred in the first half of the 20^{th} century, with the arrival of migrants coming mainly from states in the Northeast region, in the wake of a large migratory movement from this region towards the Amazon. The specialized literature indicates that two factors were decisive for rural families to decide to migrate, namely the severe and frequent droughts in the Northeast and the strong government incentive during the Estado Novo period. In the various years of droughts in the Northeast, two of them were considered decisive in decision-making, the drought of 1932-1933 and that of 1941-1944 (Freitas, Vilarino, Santos, 2019). The above scenario was widely used by the Getúlio Vargas government to encourage mass migration processes to the Amazon region, with promises of abundance and development based on water and land (Guillen, 1997).

The migrants' level of accumulation of means of production was low, so that the main means of production they brought were organic – cassava and manioc seeds, and in some cases producers had small livestock. Most of the land occupied by farmers was public land not allocated by the government (public vacant lands), with lots with a total area of 100 to 200 hectares being explored on the banks of the headwater of Lake Janauacá. In this first period, local agriculture was based on subsistence farming, with emphasis on the cultivation of cassava, beans, corn and raising of poultry and pigs. In addition to agricultural production, fishing and extractivism were activities used as a means of subsistence for families.

.As in other forest ecosystems on the planet, soil fertility was maintained based on the slash-and-burn system, which consists of a production method in which farmers cultivate a small area for a short period and then leave it fallow so that soil fertility can recover (Mazoyer and Roudart, 2010). Meanwhile, another area is cut down and burned for cleaning and subsequent cultivation, hence the name of the system, which is also known as shifting agriculture or slash-and-burn agriculture. The determining factor in a soil's ability to recover its fertility is the duration of the fallow period. In other words, the longer the fallow period, the greater the productive potential of this area will be in terms of the accumulation of biomass in the cultivated ecosystem. In the case under analysis, as land was not yet a scarce means of production, in this first phase, long fallow periods were possible.

After the first migrants settled, the second half of the 20th century can be understood as the second phase of local agrarian history. A characteristic of the period, in addition to subsistence production, is the beginning of the production of cassava by-products for the commercialization of surpluses. Although there is a certain variety of cassava by-products such as tucupi and cassava gum, there was a tendency, over time, for farmers to specialize in the production of flour. Thus, during this period there was a proliferation of so-called flour houses for processing cassava, both on dry land and in floating structures.

In this second period, access to markets was achieved by delivering products to local and regional middlemen, who organized the logistics and sale of products in the city of Manaus. Local middlemen were farmers who bought the produce from other producers and resold it to other traders who had the ability to transport the produce. In addition to the commercialization of cassava by-products, this period also saw the beginning, albeit incipient, of land commercialization. In this case, the children of farmers who acquired land to establish new production units stood out, with a consequent reduction in the size of the areas exploited. Furthermore, because of the increase in production, the greater importance of the exchange of services between workers was notable, as well as of contracts for carrying out activities inherent to cassava cultivation. In turn, with the reproduction of soil fertility, the initial strategy of use of slash-and-burn system with fallow periods lasting up to seven years was maintained.

Two external events marked the second historical period of agriculture in the headwater of Lake Janauacá. The first concerns the epidemics of malaria and other tropical diseases between the 1960s and 1980s, which impacted the local community. When analyzing the Amazon region more broadly, it is possible to identify the 1980s and 1990s as the most difficult decades in terms of malaria outbreaks; however, there are reports of localized outbreaks in other periods (Liola, Silva and Tauil, 2002; Andrade, 2015), as appears to be the case in the Novo Horizonte Community.

The second event concerns the outbreak of the so-called "Fish War", the name given to the socio-environmental conflict between farmers and fishermen on Lake Janauacá in 1973 (Santos and Santos, 2005). The reason for the conflict was that predatory fishing by fishermen reduced the fish stocks available to farmers, impacting their livelihoods. In addition to these two events, it is worth noting that in the 1980s, BR 319 highway was built, which is close to the Novo Horizonte Community. Chart 1 summarizes the three main periods of development of local agriculture.

Chart 1 | Periods and main characteristics of the agrarian history of the headwater of Lake Janauacá.

Period	Main features
Before 1955	Migration of farmers from the Northeast region and occupation of public vacant lands. Time of implementation of the slash and burn system, with subsistence farming.
1955 – 2007	Second phase of development, with maintenance of the slash and burn system and a tendency for producers to specialize in commercial flour production.
From 2007 onwards	Third phase of development characterized by the increasing agro-industrial mechanization of flour houses, through the use of electric power. Due to the increased intensity of land use, there are some experiments, still incipient, of replacing the slash-and-burn system with mechanized cultivation with the use of chemical inputs. In parallel to this, there is a tendency to diversify production, primarily with fruit and vegetable growing.

Source: Based on research data (2023).

The third phase of the development of local agrarian history began with the arrival of electricity in 2007, through the government program “Light for All”. In addition to improving quality of life, electricity impacted the production system by enabling agro-industrial mechanization. Thus, the first change made was the use of electric motors to supply water to flour houses, replacing the manual system. More recently, another innovation has been the adoption of mechanical arms to move flour in roasting ovens. In addition, the arrival of electricity allowed some producers to begin a process of productive diversification, exploring native and exotic fruit species, both fresh and processed, for consumption and sale of surpluses. In the wake of the arrival of electricity, in 2009, a local producers' association was formed, which has brought together farmers and sought partnerships with public and private institutions to obtain support for the needs of production and community life. The most recent achievement was a tractor and agricultural implements provided by the government of the State of Amazonas.

In turn, the recent dynamics of the Agrarian System have been impacted by the sharp increase in flour prices. In this regard, according to producers and data from the National Supply Company (CONAB, 2023), since 2019 the price obtained for a bag of flour has almost quadrupled, rising from values close to R$ 100.00 to approximately R$ 400.00. Among other factors, producer prices rose because of the decrease in production in the floodplain regions of the Amazon, due to floods in *El Niño* years. This fact reveals the intrinsic relationship of interdependence between the hydrological dynamics and the exploitation of agricultural zones on dry land and floodplains.

Due to the high prices of the main product from the headwater of Lake Janauacá, local agriculture has been going through a period of intensified production, in which two socioeconomic and agronomic phenomena stand out. In socioeconomic terms, it is notable that numerous producers, especially the younger ones, have invested in new structures for processing cassava flour. This phenomenon is somewhat original, since before the increase in price, it was common for young farmers to work as day laborers for other producers in order to accumulate financial resources for later investment in their own production units. However, with the high profitability of the flour, such investments have been facilitated. As a result of this dynamic, the number of day laborers available for hiring has decreased.

At the same time, the increase in the price of manioc flour seems to have accelerated an agronomic phenomenon that had already been occurring, which is the reduction of the fallow period in the slash-and-burn system. As discussed above, since the beginning of the occupation, this system has been the basis for the reproduction of soil fertility, in which long periods of fallow were carried out. However, the increase in the number of farmers, due to generational succession in a context where it was not possible to expand the areas, has already been for some years causing producers to need to reduce the fallow periods in order to increase the area planted with cassava and guarantee the social reproduction of families. In turn, the increase in the price of manioc flour has encouraged producers to further shorten the fallow period, with cases of shorter intervals, of only three years, for the reforestation of the forest being reported.

The reduction in the fallow period, whether due to the reduction in arable land or the increase in the price of flour, has put pressure on the traditional slash-and-burn system. It is in view of this problem that the Association of Local Producers, supported by technicians from the private and public sectors, has sought to develop experiments with planting cassava in a conventional system, through soil disturbance and the use of chemical fertilizers to reproduce fertility.

Finally, it is worth highlighting the existence of an intense process of experimentation by certain farmers in the community, in which two trends can be distinguished. The first is the development of production systems based on various cultivated and wild species with distinct production cycles, combined or in single cultivation, mainly cupuaçu, watermelon, papaya and corn. The other trend, still embryonic and in the testing phase by the producers' association, is the abandonment of the system based on forest fallow in favor of the implementation of mechanized cassava cultivation, with the use of chemical fertilizers, liming and pesticides. In this regard, an important characteristic of this process of experimentation, common to both trends, is that it is based on a radical change in the technical basis of the production system through the increasing use of fossil fuels and chemical inputs and, in general, on a greater level of accumulation of means of production.

In the 20th and 21st centuries, throughout the various evolutionary stages of agriculture, artisanal activities such as fishing and extractivism have maintained their integration and synergy with the main subsystems of cultivation and breeding. Historical and ecological conditions such as know-how and the conservation of natural ecosystems have allowed these ancestral practices to be preserved in the way of life of communities. In summary, the strategy adopted is an important contribution of diversified and healthy food to families, in addition to supplementing agricultural income in some situations.

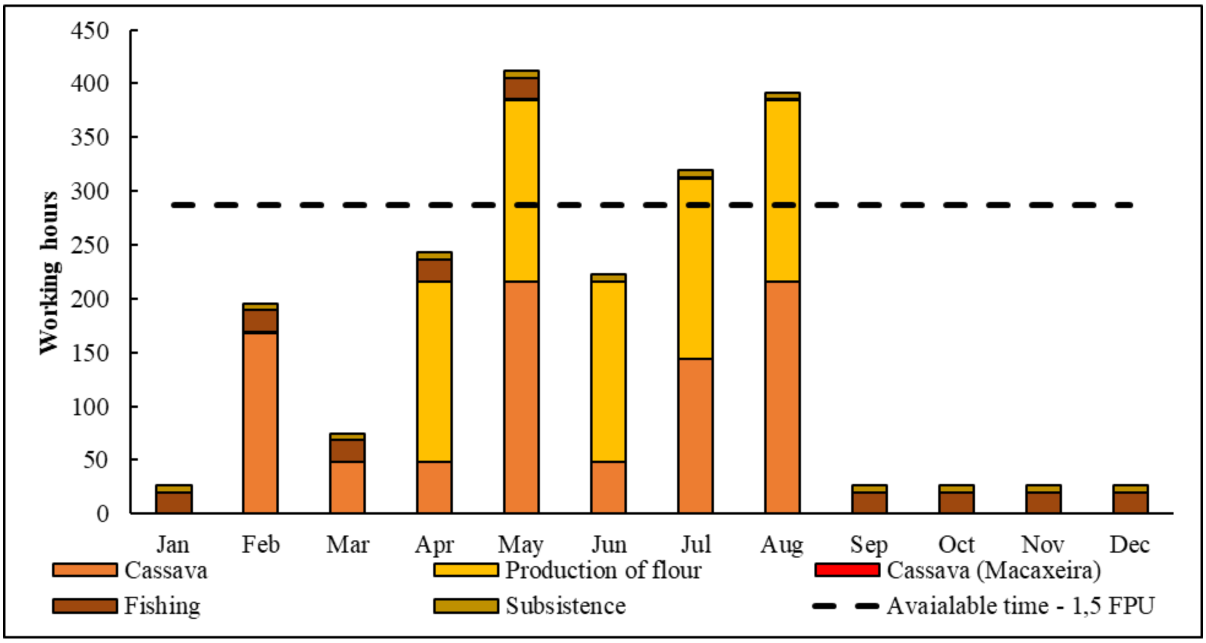
AGROECONOMIC CHARACTERISTICS OF PRODUCTION SYSTEMS

The historical formation discussed in the previous section gave rise to the formation of different accumulation trajectories and, therefore, different production systems. The data and information acquired allow the identification of a main type of farmer, whose characteristics can be observed in many local production units, and which is here referred to as the “Family Farmer - Complete Cycle Flour House” (AF-CFCC). Due to recent developments in the history of agriculture, two other cases of production systems with different dynamics will be presented, namely: “Family Farmer - Cassava, Cupuaçu and Non-Agricultural Income” (AF - MCRNA) and the “Diversified Employer Farmer” (AP-D). These two cases represent incipient production systems in the local agrarian dynamics.

The Family Farmer’s Full Cycle Flour House has his social reproduction mainly ensured through the sale of flour, which is entirely cultivated and processed in the agricultural production unit. The full cycle refers to the fact that this farmer has the entire set of machines and equipment necessary for the production of flour, from the production of cassava to its processing in the so-called flour houses.

The agricultural calendar for cassava cultivation begins in May, when producers perform the so-called “brocado” (a process called “brocado”), which consists of cutting down the forest to later establish the year’s cassava field. Later, in June, farmers harvest the cassava stems of the year, to be planted again in August. However, one month before planting, in July, producers burn and clear the land. During September, the first mechanical weeding of the crop takes place, using motorized mowers. The second and final weeding (called “bateção”) is done in February. The cassava harvest and flour production last for five months, between April and August. Figure 3 shows the itinerary of the development of activities and the number of hours worked by AF-CFCC.

Figure 3 | Itinerary and time for the development of AF-CFCC productive activities.



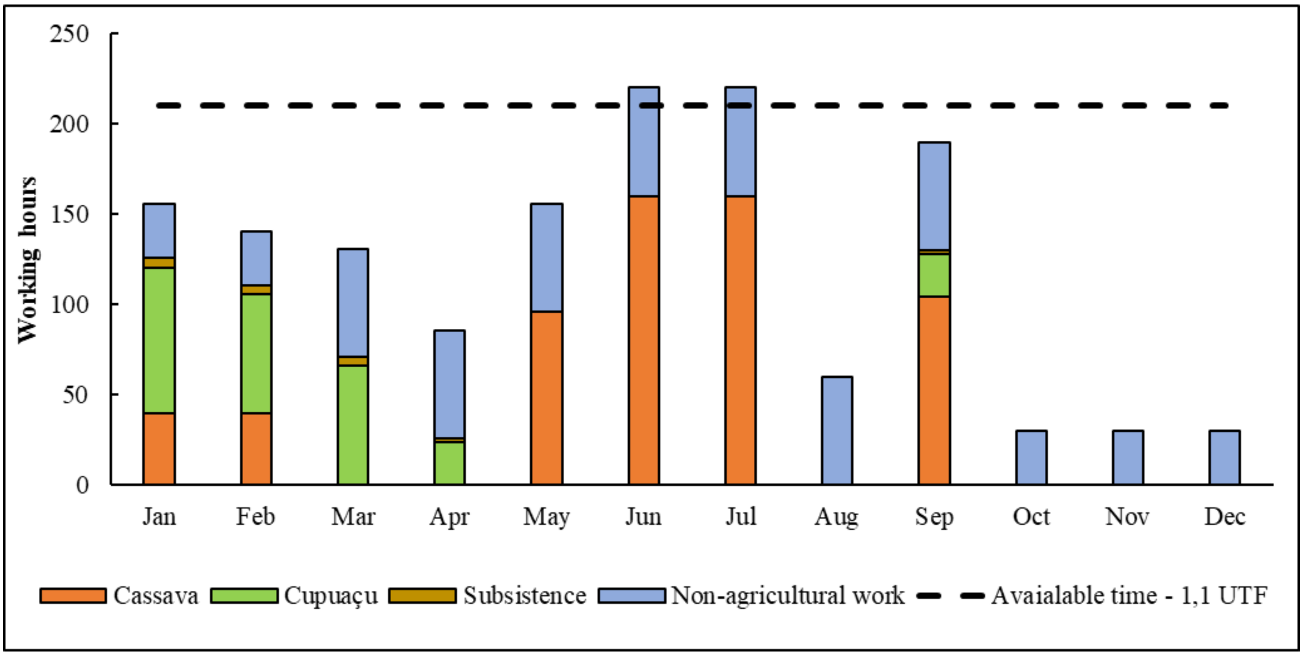
Source: Prepared by the authors based on research data (2023).

From the point of view of time use, Figure 3 shows that this is a type of farmer whose available labor force, of 1.5 labor units[1], is insufficient in three months of the year (May, July and August), mainly reflecting the overlapping of activities related to cassava management and flour production. In the month of May, work overload occurs because during this month farmers both clear the land for planting the year's cassava, as well as harvesting and making flour. In July, overload occurs because, together with harvesting and making flour, producers need to burn and clear the new field. Finally, in August, the last month of harvesting and making flour, it is time to plant the new cassava field that will be harvested the following year. It should be noted that during these peak work periods, farmers extend their working hours, working more than 44 hours per week. In the other months of the year, the labor force is more available. In addition to flour production, this type of farmer also produces and sells cassava and fish, although this is secondary to flour. In addition, it is common for farmers to have crops and livestock for subsistence.

1 In this study, one Work Unit (WU) was considered to be equivalent to the availability of 191 working hours per month. This availability was calculated considering an average number of 4.35 weeks per month and that 44 hours are worked each week. Thus, in the case of AF-CFCC, which has 1.5 WU, 287 hours of work are available per month.

As previously mentioned, two cases of farmers with less common production dynamics will be addressed, compared to the AF-CFCC. The first of them is of a family of farmers who produce cassava, cupuaçu pulp and develop non-agricultural activities and are therefore called Family Farmer Cassava, Cupuaçu and Non-Agricultural Income (AF-MCRNA). In this specific case, the cassava is not processed to make flour, since the producer works the field "half-crop". This type of production arrangement is made up of two farmers, the owner of the field and a sharecropper, usually the owner of a flour house. Thus, the farmer who owns the field is responsible for managing the cultivation from planting to harvest. At the time of harvest, the owner of the field harvests half of the field and delivers the product for flour production to the sharecropper, who is responsible for making the flour and harvesting the other half of the cassava field. The flour production, carried out by the sharecropper, is divided into two parts, half for the owner farmer and the other half for the sharecropper farmer. Figure 4 shows the activities and the working time of the AF-MCRNA.

Figure 4 | Itinerary and time for the development of AF-MCRNA productive activities.



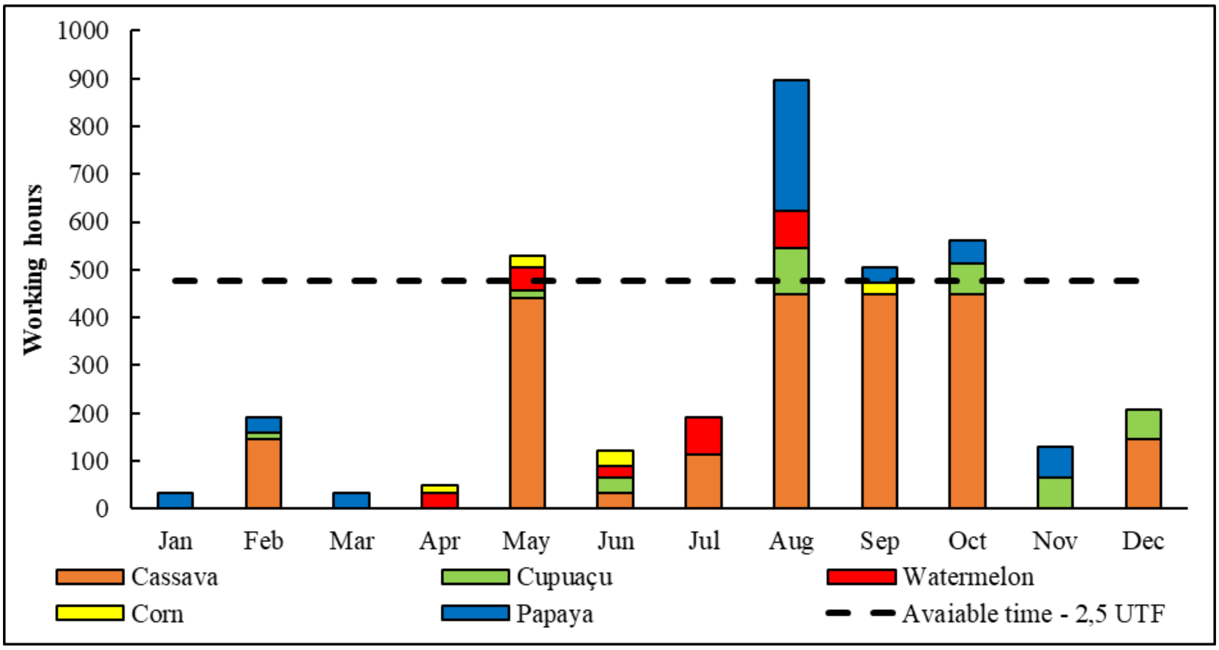
Source: Prepared by the authors based on research data (2023).

The activities developed by AF-MCRNA in cassava cultivation are similar to those of AF-CFCC, except that AF-MCRNA has a smaller amount of available labor (1.1 UTF) and therefore hires workers to carry out the "brocado", slash-and-burn and planting of cassava in the months of May, June, July and August. In addition to the production of cassava, combined with the production of cupuaçu, this worker carries out non-agricultural work, producing wooden canoes.

Analysis of the use of time shows that during the months of June and July there is an overload of labor, especially due to operations with cassava, but also because this is a month in which non-agricultural work takes up 60 hours of work (Figure 4). The activities carried out on the cassava farm in the months of June and July consist of harvesting half of the crop and preparing the land for planting the new crop. As for the production of cupuaçu, this is carried out in an extractive and artisanal manner, since from January to March the producer harvests the fruit, while from January to April the pulp is extracted for sale through middlemen.

The second case of a farmer, named Diversified Employer Farmer (AP-D), is based on the diversification strategy through the production of cassava, watermelon, papaya, cupuaçu and green corn. From the point of view of the use of available family labor (2.5 UTF), the months of May, August, September and October represent the critical points in the calendar for labor (Figure 5). In May, operations for establishing cassava crops, such as "broca", use almost all of the available labor. In August, the month with the highest labor demand, the combination of labor demands for the cultivation of cassava, papaya (soil preparation, liming, digging holes and fertilizing, cassava planting, harvesting and scraping), cupuaçu (digging holes, applying correctives and insecticides) and watermelon (harvesting and transportation), has a peak close to the total available family labor. In September and October, the harvesting of green corn and cassava coincides with the cultivation of papaya and cupuaçu.

Figure 5 | Itinerary and time for the development of AP-D productive activities.



Source: Prepared by the authors based on research data (2023).

Given that the Diversified Employer Farmer has 2.5 Family Labor Units and that there is an overload of work in four months, this type of producer needs strategies to meet the demand for labor, such as hiring day laborers, exchanging services, and introducing machinery into the production system. Thus, labor is hired in six months of the year (February, May, August, September, October, and December) and is used mainly for the cultivation of cassava, in operations of clearing the field, planting, and harvesting. Unlike the main type, the AP-D does not have a flour house. Therefore, they harvest the crop and sell it to other farmers who carry out the processing. The hired labor is also used in the month of August in the cultivation of papaya trees, in fertilization operations, and throughout the year the producer needs the equivalent of 0.6 Labor Units. It should also be noted that this type of nomenclature is used because the production system needs to hire labor, since family labor does not fully meet production demands.

Based on the calendar of activities and some of the characteristics of the types of farmers presented, Table 1, below, allows an analysis of the main economic indicators of the three production systems. It can be seen that the areas are varied, but none of the cases investigated has more than 25 hectares of usable agricultural surface, even though the total area is larger. In fact, this is a regional characteristic commonly found in the field, since according to the Brazilian Forest Code (BRAZIL, 2012), at least 80% of the area must be designated as a Legal Reserve in forest areas in the Legal Amazon. These areas can only be used economically in a few situations, such as the management of agroforestry systems, which can be undertaken as long as they do not disrupt native vegetation and are operated by family production units. Thus, it can be seen that only AP-D cultivates more than 20% of the total surface (Table 1).

Table 1 | Economic indicators of the production systems studied.

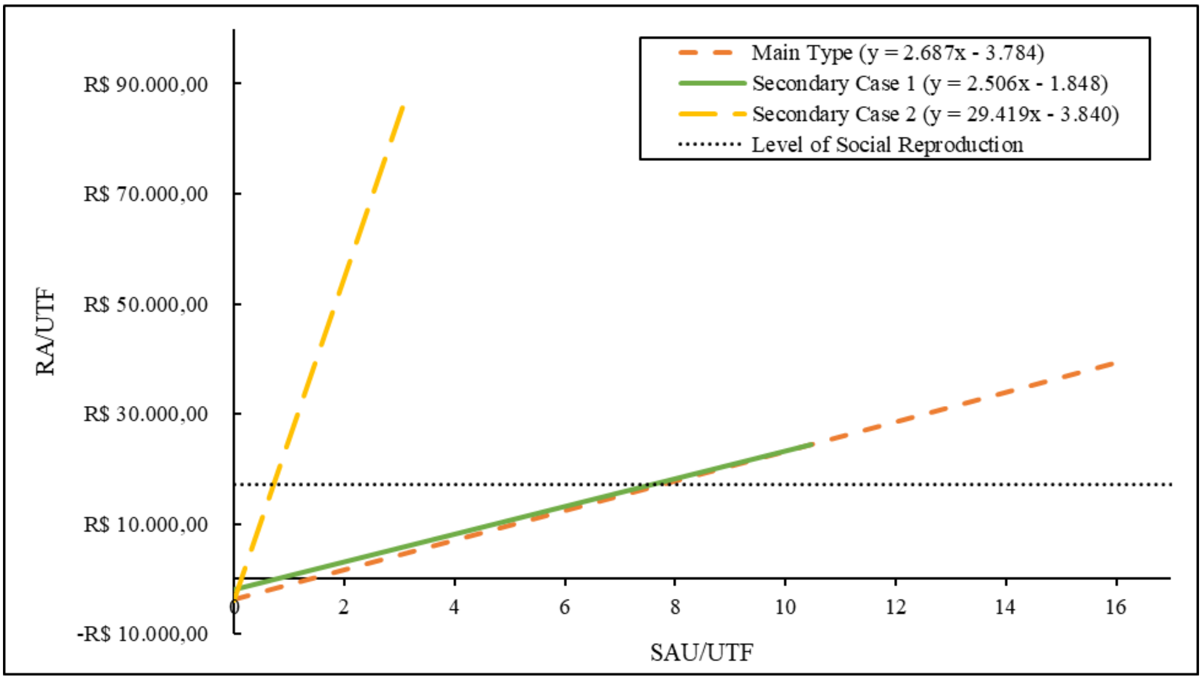
Indicators	Main Type AF-CFCC	Secondary case 1 AF-MCRNA	Secondary case 2 AP-D
Total Surface	120.5 [1]	62.5	36
Usable Agricultural Area capable of being used according to the Forest Code [2]	24.1	12.5	7.2
Usable Agricultural Area	24.1	11.5	7.9
Family Production Unit (UTF)	1.5	1.1	2.5
Contracted Work Unit	0	0.1	0.6
Gross Production	R$ 68,320	R$ 39,300	R$ 287,377
Intermediate Consumption	R$ 2,735	R$ 4,383	R$ 36,856
Depreciations	R$ 5,675	R$ 2,032	R$ 12,042
Distribution of Added Value	R$ 945	R$ 6,094	R$ 16,377
Added Value	R$ 59,910	R$ 32,885	R$ 238,478
Agricultural Income (RA)	R$ 58,965	R$ 26,792	R$ 222,101
RA/UTF	R$ 39,310	R$ 24,356	R$ 88,841

[1] Estimate made based on data provided by the producer.
[2] Area calculated considering a possible use of 20% of the Total Surface.

Source: Prepared by the authors based on research data (2023).

Considering the three production systems presented, it can be seen that, compared to the others, AP-D shows a significant movement of means of production, since the gross production is R$287 thousand per year. However, the high expenditure on inputs and on the payment of daily wages to third parties in the production of cassava by this farmer causes a significant drop in agricultural income. Thus, the economic data point to a greater externalization of the AP-D production system, both related to the greater and considerable use of inputs and the dependence on labor. When comparing the Main Type and Secondary Case 1, it is noted that while Main Type has greater investment due to the existence of the flour house, Secondary case 1 has a greater distribution of added value due to the payment of daily wages. These data are key for the analysis of agricultural income and the social reproduction capacity of farmers. The following graph illustrates these variables (Figure 6).

Figure 6 | Linear models of the social reproduction capacity of production systems.



Source: Prepared by the authors based on research data (2023).

The data above allow us to state that all the production systems analyzed are capable of generating sufficient income to reach what we are calling the Level of Social Reproduction[2]. In other words, they produce an income per person that is greater than the income they would eventually receive if they worked as salaried workers in other non-agricultural activities. This means that there are material conditions for them to remain in the countryside, countering the processes of rural exodus and the precariousness of material production conditions.

However, it should be stressed that the conditions through which income is produced differ from an agroeconomic point of view. For example, secondary case 1 (AF-MCRNA) and the main type (AF-CFCC) have a similar income generation potential per hectare (angular coefficient of the linear model of approximately R$ 2,600.00 per hectare); however, the former, without a flour house and producing “half-crop”, has a smaller production area.

As discussed above, during the elaboration of the study it was noted that the prices of flour received by producers are above their historical average. When a simulation of price drops for the two types of flour producers (AF-MCRNA and AF-CFCC) is performed, it is noted that to ensure sufficient income to reach the NRS, the price of flour for AF-MCRNA can fall by a maximum of 24%, from the current R$ 400.00 per 50-kg bag to a minimum of R$ 308.00. For the main type (AF-CFCC), the margin of decline is greater, so that to maintain the reproduction level the price can fall by 67%, decreasing from the current R$ 420.00 received by the producer to up to R$ 138.00 for the 50-kg bag of flour.

As for the secondary case 2 (AP-D), it is the production system with the highest income per person, totaling R$ 88,840.54 per year. Furthermore, this income is produced on a smaller area than the other two farmers, which shows its high potential for generating income per unit of usable area, with an angular coefficient of nearly R$ 30,000.00 per hectare. In turn, the lowest income of all is observed in secondary case 1, which as treated has a potential for generating income per area similar to the main type, but because it has a smaller area, it reaches an income per person of R$ 24,356.06. In summary, secondary case 2 with diversified production systems is capable of producing a higher income in smaller areas, while secondary type 1 generates the lowest income per person, even though it is higher than the level of social reproduction considered.

2 The minimum income for the Social Reproduction Level was considered to be an income of R$ 17,160.00 per year. This is equivalent to a monthly minimum wage (R$ 1,320.00), plus the 13th salary in effect in 2023.

AGRICULTURAL PERSPECTIVES AND STRATEGIC GUIDELINES FOR PROMOTING LOCAL DEVELOPMENT

In order to carry out an adequate analysis of the community's agricultural prospects based on the results obtained in this study, it is first necessary to consider the specific context in which the study was conducted. It was found that the high prices of cassava flour are due to the failure of the cassava harvest in floodplain crops, especially those in the state of Pará. In this context, the high prices of flour led to a significant increase in the number of farmers dedicated to cassava cultivation, many of whom were former day laborers and children of farmers who began to cultivate plots of land that belonged to their families.

It should be emphasized that high cassava prices have not led to a decline in the community's agriculture. On the contrary, they have contributed significantly to its strengthening, since the economic data show the social reproduction capacity of farmers. However, the main and most worrying component of this recent dynamic is a search for a change in the technical basis by replacing forest fallow with continuous crops based on inputs and equipment of industrial origin, with some diversification of production.

It is likely that this trend of change in the technical basis is caused, essentially by the difficulty of ensuring adequate maintenance of the productive potential, that is, of the reproduction of the fertility of the agroecosystems, from the forest fallow, given the reduction in the cultivable area (and consequently the reduction in the fallow period) due to the increase in population. Thus, it is likely that, even in the face of a fall in the price of cassava, the use of inputs and equipment of industrial origin will increase. Additionally, the diversification of production with species of grains, vegetables and fruits, especially those for in natura consumption, can be dramatically affected by the adverse climatic conditions during their productive cycle and by the indirect effects on the conditions for transporting the harvest, basically via rivers to the local branches.

A technical-economic analysis of cassava crops based on industrial inputs and equipment was not possible because changes in the local agricultural system are incipient. Therefore, it is not known whether the technical changes and consequent increase in the expected yield will be sufficient to compensate for the high increase in production costs. On the other hand, the negative impacts of this cultivation system are more predictable. First, it was found throughout the study that the soils used for cassava cultivation, including those being used for crops based on industrial inputs and equipment by the AP-D, are highly susceptible to erosion, as they present a strong contrast between the surface horizon, sandy loam, and the subsurface horizon, clayey, of "textural type B".

Moreover, the continuous cultivation of cassava or other crops such as sweet corn and watermelon, which have low vegetation cover, on such soils, subject to the heavy and intense rainfall that characterizes the region, can cause a strong erosion process, with highly negative effects on soil yield, as well as on the region's watercourses. Finally, it should be said that ceasing to use fallow land and opting for continuous crops would cause a significant reduction in forest cover, with all the negative consequences for the environment that such a reduction implies.

Based on the results of this study, some strategic lines for promoting the development of agriculture in the Novo Horizonte community could be discussed, with a view to sustainability. Strategically, the trends described above indicate important aspects to be considered for the creation of measures to promote the development of local agriculture. On the other hand, it is also important to consider the reasonable capacity for social reproduction of the farmers in the community, ensured by the production systems currently used, especially with regard to systems based on forest fallow and the synergistic exploitation of artisanal fishing and forest extraction.

Therefore, strengthening fallow-based systems has a key strategic importance. Such strengthening requires measures capable of counteracting the (possibly increasing) difficulties in reproducing the fertility of fallow-based systems. Such measures could range from selective use of fertilizers to the establishment of crop succession that point to the full development of agroforestry systems.

Another set of strategically important measures concerns improving the mechanization of cassava flour manufacturing operations, given the significant number of hours of work needed for such production. Although many of these operations are already mechanized, often with equipment developed in the community itself, some of them are still manual. For example, peeling cassava and transporting it from boats. On the other hand, activities related to sustainable forest management, considered part of the bioeconomy, particularly those involving the collection and/or processing of native fruits, also deserve support through the capacity-building strategy.

FINAL CONSIDERATIONS

Resuming its objective, this study attempted to characterize and analyze the environmental and economic sustainability of the production systems of the Novo Horizonte community, and some considerations should be made here. Based on the results obtained through the analysis of the local agrarian system, two aspects stood out. The first is the good technical and economic performance of flour production based on forest fallow systems, which provide relatively high physical yields, greater than 12 t/ha. Despite the current high prices of cassava flour, such yields, combined with extremely low monetary costs, mean that cassava flour produced from systems based on forest fallow, even in relatively small areas, can ensure good conditions for the social reproduction of farmers. In this sense, it should be noted that the main innovations adopted by farmers were directed towards mechanization, especially in flour production, while maintaining the fertility reproduction method based on fallow land practically unchanged to date. In other words, it can be said that the production systems currently developed to date are economically and environmentally sustainable, given that they have maintained the slash-and-burn system.

The second aspect that stands out is the great dynamism of the region's farmers. The innovations introduced into the production process, especially the mechanization of much of the flour production, were largely carried out by farmers (or other professionals) from the region itself. These improvements have significantly reduced the length and hardship of labor, which, as found in this study, is still quite high, especially considering certain periods of greater labor demand. On the other hand, this same dynamism is also evident in the tendency to replace the system based on forest fallow with systems based on continuous cultivation, with intense use of chemical inputs, industrial equipment and the hiring of labor during peak work periods.

As mentioned, this change was probably greatly stimulated by high flour prices, which led farmers to believe that increased expenditure on means of production could be offset by more intensive land use. In short, the increase in the prices of products (in this case, flour) had a negative effect on the maintenance of the system based on forest fallow. Consequently, in order to increase the price of flour to improve the income of farmers using this system, such an increase must be accompanied by a rise in the prices of chemical inputs and industrial equipment, so that the change of system is discouraged. In other words, the maintenance of systems based on forest fallow, which play a crucial role in the ecological sustainability of community agriculture, could be stimulated by a price system defined by the State (Silva Neto, 2021). Unfortunately, the lack of data on crops in a continuous system did not allow us to make any estimates in this regard.

In any case, it is important to emphasize that the results obtained in this study, which attest to the great dynamism of the community's farmers, do not corroborate the proposals for agricultural development formulated within the scope of the so-called "modernization theories" (Schultz, 1965). One of the main assumptions of these theories is that "traditional" agriculture, i.e. the one based on production systems developed by the farmers themselves, generally with low use of inputs and equipment of industrial origin, does not have the capacity to develop, and for this reason it should be replaced by "modern" agriculture, that is, agriculture based on the large-scale use of chemical inputs and equipment of industrial origin.

The theory of agrarian systems (Mazoyer, Roudart, 2010; Dufumier, 2004 and 2010) rejects the dualistic conception adopted by the theory of modernization, which classifies agriculture as "traditional" or "modern". On the contrary, the theory of agrarian systems argues that contemporary agriculture is composed of a large number of agrarian systems, originated from a long process of historical evolution and geographic differentiation, resulting in a multitude of types of agriculture, in constant movement and with specific characteristics that should be understood in depth, so that appropriate measures for their development can be defined. Therefore, according to the theory of agrarian systems, only from this understanding can one evaluate the real potential for development of agriculture in a given location. The findings of the present study strongly corroborate this pluralistic conception of agriculture, in historical and geographic terms, proposed by the theory of agrarian systems. Thus, the great potential of the agrarian systems approach for assessing the diversity of agriculture in terms of its capacity for adaptation and resilience to the economic and environmental problems faced by contemporary societies, such as, for example, the problems caused by climate change, should be highlighted.

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