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The economy of agroforestry systems in the Amazon: a critical trajectory for sustainable development (1995-2017) *

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Abstract

The article provides an extensive, in-depth analysis of the economy of Agroforestry Systems in the Amazon using census data (1995, 2006 and 2017) and results from different primary studies. Describing the evolution in the region as a whole and in the territories of the leading peasantries, it highlights the concurrence of technological variants and its outcome. For each territory and peasantry, the fundamentals of the income variation, both in micro and macro level, are discussed, particularly the physical productivities and trade terms. The main results highlight the systematic growth of the SAF economy for two decades, with increasing net labor income and productivity in the first and constant labor income and decreasing productivity in the second. By guaranteeing greater net income from family work, the SAFs-A variant has become the most important, asserting itself, with different formats, in all territories. Economic efficiency varies across territories according to the dominance of technological variants: growing continuously where SAFs-A prevail and stagnating, or decreasing in a recent period, where SAFs-F dominate. These are strategic policy questions, which suggest urgently providing the economy of agroforestry systems with an institutional environment adjusted to their singularities.

Keywords: Agrarian Dynamic in Amazonia; Agroforestry Systems (AFS) in the Amazon Region; Peasant Economy Brazilian Amazon.

Resumo

A economia de Sistemas Agroflorestas na Amazônia: uma trajetória crítica para o desenvolvimento sustentável (1995-2017)

O artigo traz uma análise extensa e aprofundada da economia dos Sistemas Agroflorestais na Amazônia usando dados do censo agropecuário (1995, 2006 e 2017) e resultados de diferentes estudos primários. Descrevendo a evolução da região como um todo e dos principais territórios camponeses na Região Norte, destaca a competição das variantes tecnológicas e o seu resultado para cada território e campesinato, discutindo os fundamentos da variação do rendimento, tanto a nível micro como macro, particularmente a produtividade física e os termos comerciais. Os principais resultados destacam o crescimento sistemático da economia de SAFs durante duas décadas, com aumento do rendimento líquido do trabalho e da produtividade na primeira e rendimento constante do trabalho e diminuição da produtividade na segunda. Ao garantir maior rendimento líquido do trabalho familiar, a variante SAFs-A tornou-se a mais importante, afirmando-se, com diferentes formatos, em todos os territórios. A eficiência económica varia entre territórios de acordo com o domínio das variantes tecnológicas: crescendo continuamente onde os SAF-A prevalecem e estagnando, ou diminuindo num período recente, onde os SAF-F dominam. Estas são questões estratégica de política, que sugerem dotar urgentemente a economia dos sistemas agroflorestais de um ambiente institucional ajustado às suas singularidades.

Palavras-chave: Dinâmica agrária na Amazônia; Sistemas Agroflorestais na Região Amazônica; Economia Camponesa na Amazônia Brasileira.
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Introduction

In 2007, the influential IPCC Stern Report identified Agroforestry Systems (AFSs) – productive systems composing forest, agriculture, and livestock (Atangana et al., 2013, p. 35-36) – as a pathway of low environmental impact and great resilience, and as being favorable toward sustainable development in the Amazon (Stern, 2007, p. 603-621). The recently launched Assessment Report of the Science Panel for the Amazon (SPA, 2021) emphasizes this point, highlighting in different chapters the presence of a peasant economy based on AFSs, which would be the premise for a "bioeconomy of the standing forest and flowing rivers" (Abramovay et al., 2021), requiring urgent strengthening political actions. This would enhance its capacity to resist the tensions arising from ongoing aggressive socioeconomic processes that destroy nature and ways of life (Costa et al., 2021). One recognized weakness is that the knowledge regarding AFSs has remained rarefied, specific, and localized, in space and time – as previously indicated by Hecht (2010) and Porro et al. (2012).

Indeed, research conducted in the Amazon region throughout the late 1980s and the entirety of the 1990s unveiled different forms of agroforestry systems (AFSs).Various studies have scrutinized the technical, economic, and social dimensions of AFSs among riverine communities in the estuarine zone (Anderson; Jardim, 1989; Anderson; Ioris, 1992; Anderson et al., 1995; Jardim; Anderson, 1987; Hiraoka, 1994; 1995), as well as among upland agriculturalists in Tomé-Açú (Subler; Uhl, 1990; Subler, 1993; Yamada, 1999; Teixeira et al., 1994), Capitão Poço, and Irituia (Costa, 1996; 1997 a; 1997b), the Transamazonica Road Region (Smith et al., 1996), and Rondônia (Browder et al., 2000). Subsequent investigations by Brondizio (2008) on Marajó, de Canto (2007), McGraph et al. (2007), and Scroth et al. (2003) on the lower Amazonas, Lima (2005) and Neves (2005) on the middle Amazonas, and Sulisbury and Schmink (2007) on Acre, have underscored the widespread regional prevalence of AFSs, emphasizing their diverse manifestations and evolutionary trajectories across distinct locales.

Despite this, research endeavors have not significantly intensified since then, leaving broader questions largely unaddressed: to what extent does the Amazonian economy rely on AFSs? What are the primary technical and economic drivers shaping their evolution? Where are they most prominent, and who are the key stakeholders?

Nevertheless, recent studies from a political economy perspective have laid important groundwork for a more holistic understanding. Costa's (2021, 2009) structural portrayal of the agrarian economy in Brazil's Northern Region (NR) spanning from 1995 to 2017, conceptualizing it as a complex, evolving entity shaped by techno-productive trajectories – productive trajectories and their technological variations (Dosi, 1988) – has delineated six overarching trajectories, comprising three patronal (wage-based) and three peasant (family-based) trajectories, with one of the latter, labeled T2, encompassing AFSs.

Building upon this insight, this article aims to furnish a comprehensive, in-depth analysis (essential for strategic sustainability) of the AFSs economy in Brazil's Northern Region – an unprecedented endeavor elucidating its structures, charting its evolution across the region and within the territories of prominent peasantries, and elucidating the interplay of technological variations and their outcomes. It delves into the determinants of income variability at both micro and macro levels, particularly focusing on physical productivities and trade dynamics within each territory and peasantry.

This endeavor is justified by the imperative for policymaking to be cognizant of the specific characteristics and modes of existence of this strategic economy for ensuring sustainability in the Amazon, Brazil, and globally.

Section 1 presents the conceptual frameworks that guide the analysis and historically defines the leading peasantries of T2 and its territories. Section 2 analyses the evolution of aggregated pecuniary and institutional variables, situating T2 amongst the other techno-productive trajectories evolving in rural Brazil's Northern Region from 1995 to 2017. Section 3 defines the trajectory in the territories and peasantries: in the subsections, results from different studies on the evolution of AFSs in the Amazon are linked with an analysis of the T2 technological variants and their productive systems, enabled by agricultural censuses data. Section 4 reveals the income variations and results from the formation of T2 regarding the technological variants and peasantries. Following this, the fundamentals of the income variation are discussed, particularly the physical productivities and trade terms. Lastly, considering the realized trends, amongst the final considerations, relevant issues will be indicated for strategic political action.

The databases, descriptions of methodologies and special tabulations for this article are housed in Costa, 2022 and Costa et al., 2022 and will be referred to when necessary, throughout the text.

1 Peasants, Amazonian peasantries, and their territories

T2 is an economic structuration led by peasants clustered in peasantries. A vast literature, mostly cited ahead, indicates that, contrary to what is often assumed, peasant realities, particularly in the Amazon, and furthermore, those dealing with extractivism are extraordinarily dynamic and diverse. It is therefore essential that the theoretical resources used are able to face the challenging issues of change and diversity (Long, Ploeg, 1994).

1.1 The specificity of peasant decision-making rationality

From a Chayanovian economic perspective, the specificity of "peasant enterprises" lies in the significance accorded to the reproductive needs of the family within the decision-making process, as it constitutes an inseparable unit bridging the realms of production and consumption for those involved (Chayanov, 1923). Consequently, economic activities are organized based on domesticity criteria (Sahlins, 1972; Polany, 1992), wherein two key concepts are pivotal. Firstly, the forces arising from opposing tensions – stemming from the necessities driving labor and the associated strains of its execution appealing to leisure – shape a reproductive pattern (RP), encompassing consumption habits and productive routines to fulfill it. Secondly, both in terms of measures ensuring RP in the short term and decisions aimed at its long-term maintenance, the peasant production unit is governed by its labor capacity: the number of workers, their available working hours, and their tangible and intangible skills.

Neoclassical subjectivism reduced these seminal ideas to microeconomic theories, dominated either by a risk-averse-peasant (Liptom, 1968) or by a drudgery-averse-peasant (Nakagima, 1969; Elllis, 1988). Tepicht (1973), in turn, establishing a Marxist structural perspective in absorbing Chayanovs ideas, suggested that, the “Chayanovian” balances between the family needs and capacity, result in an interaction with a market institutional environment in a necessary pathway of changes. These, however, oriented fiercely by external needs and tendencies, inescapably lead to industrialist specialization and intensification and, ultimately, to the very emptying of peasant specificity.

The perspective used herein understands that interactions between the internal conditions of the peasant units and those of their external relations, referred to constraints given by evolution of the family, may lead to both dynamics of change and to states of accommodation – hence, microeconomics prevail, featuring however non-linear behaviors. These depend on the *reproductive efficiency* (RE) defined in this interaction - the most important variable that synthesizes the system's operating conditions (Costa, 2019, p. 127-128). Synthetically:

$$RE = \frac{H_T}{H_E} = 1 + \frac{p_v}{p_c}\frac{r}{c}\frac{W}{C} \tag{1a}$$

Where:

H_T = Total family’s applicable worktime;

H_E: Portion of H_T applied to guarantee a reproductive pattern (RP);

P_V: Price for sale of products and services;

p_C: Price of inputs purchase;

r: Physical productivity of the family’s adult-equivalent-worker;

c: Consumption needs per family’s adult-equivalent-consumers;

W: Number of family’s adult-equivalent-workers;

C: Number of family adult-equivalent-consumers;

$\frac{r}{c}$: Internal conditions of production-reproduction;

$\frac{p_v}{p_c}$: External relations with market to meet RP;

$\frac{W}{C}$: Balance workers-consumers.

The terms of reproductive efficiency in (1a) encompasses two key components within the realm of economic analysis. The first component pertains to productive and economic efficiency, quantifiable as the net income of the family worker (NI_{FW}). The second component addresses the conditions for family reproduction (RC_{FC}). Therefore, equation (1a) can be rewritten as follows:

$$RE = 1 + NI_{FW}.RC_{FC} \tag{1b}$$

Where:

$$NI_{FW} = \frac{p_v.r}{p_c} \tag{2}$$

$$RC_{FC} = \frac{W}{c.C} \tag{3}$$

Relation (2) is an index of the average payoff of family worker:

$$NI^*_{FW} = (p_v - p_c).\mathrm{r} \tag{4}$$

So that (2) and (4) move in same way:

$$\Delta NI_{FW} = \Delta NI^{*}_{FW} = \Delta r + \Delta(p_v - p_c) \tag{5}$$

The greater relationships (1a,b), the greater the fluidity and ease, and therefore, less tension in maintaining the reproductive pattern; on the other hand, the subjective assessment by family members is more positive on the efficiency of their strategy. The systemic rationality of the peasant unit is such that the growth on the right side of equation (1a) is transformed into reproductive efficiency, either by reducing H_E or by increasing H_T (Costa, 2019, p. 127-128; 2012, p. 101-115).

In the peasant economy, the propensity for productive investments, technological changes and innovations that would allow maintaining RP in a future in which needs grow with the age dynamics of families, depends on reproductive efficiency and is expressed in a non-linear, parabolic manner:

In instances where reproductive efficiency (RE) is high, the peasant unit may experience a "state of affluence", as defined by Sahlins (1973). Consequently, there is a diminished inclination for change, and the family unit exhibits a tendency to avoid risk (Lipton, 1968) and arduous labor (Ellis, 1988; Nakagima, 1969).

In the provided context, the eventual enhancement of trade terms and productivity tends to result in an augmentation of RE by diminishing the magnitude of applied family labor, denoted as H_E, through two distinct processes: initially, products possessing comparative advantages (higher NI^{*}_{FW}, see (4)) prevail over others, as their supplies correlate directly with respective prices; subsequent to the exhaustion of this substitution process, another phase ensues, potentially characterized by inverted supply dynamics (Costa, 2019, p. 138; Costa, 2012, p. 108). Within these circumstances, only incremental innovation and adaptive adjustments occur, often supported by labor savings facilitated by the mentioned mechanisms of inverted supply.

If, however, the reproductive efficiency falls systematically, and becomes insensitive to incremental changes, which characterizes the reproductive pattern crisis, the propensity for structural, radical changes increases and attitudes towards risk and stress are reversed (Costa, 2019, p. 144-145; 2007a: 301-305). Thus, changes will occur: a) in new combinations of the internal endowment of land, labor and capital that alter the extended use of availabilities: "adjusting the set of availabilities to the minimum available factor" (Chayanov, 1923, p. 42); b) in the domestic production of elements of capital, in a process that Tepicht termed "intensification I" (Tepicht, 1973, p. 28-29) – in this case, spared work on account of better external relations may be used, and c) by internalizing new resources of external origin ("intensity II", for Tepicht), i.e., expanding the internal resources of land and capital, tangible and intangible, through the market and other institutions. The forms that change in an intensity II route depend on the competitive stage of the technological paradigms and trajectories on local, national and global levels (Costa, 2012, p. 141-145).

From the viewpoint of those involved, reproductive conditions (3) continually shape decision-making considerations. Nonetheless, a pivotal criterion for validating the trajectory of change lies in the dynamics outlined in equations (2) and (4). By elucidating the interplay between internal production circumstances and external trade relations, variations in NI^{*}_{FW} form the basis for expectations concerning the reproductive efficiency of a given reproductive pattern. Stability and the concomitant reduction of risk are enhanced with an expansion in the diversity of products and their applications. However, the risk-reducing role of diversity may be supplanted by institutional mechanisms (Costa, 2012, p. 129-140; 2007b, p. 148-149).

1.2 Amazonian peasantries

Peasantry signifies the set of peasant families in a territory, which, by providing them with the immediate natural and social context of reproduction, accommodates their history and amalgamates their specific commonality and livelihood (Costa; Carvalho, 2012, p. 113). In a peasantry territory, local productive arrangements operate, which link the peasant microstructures, on one side, with infra-structural and public services in territorial governances (Costa; Fernandes, 2016) and on the other, with short value chains, related to local needs (Soares; Costa, 2013), and long chains, related to national and world markets (Costa et al., 2021b). The specificities of these institutional and economic arrangements combined with those of the natural fundamentals of production explain the diversity of peasantries and their evolving pathways.

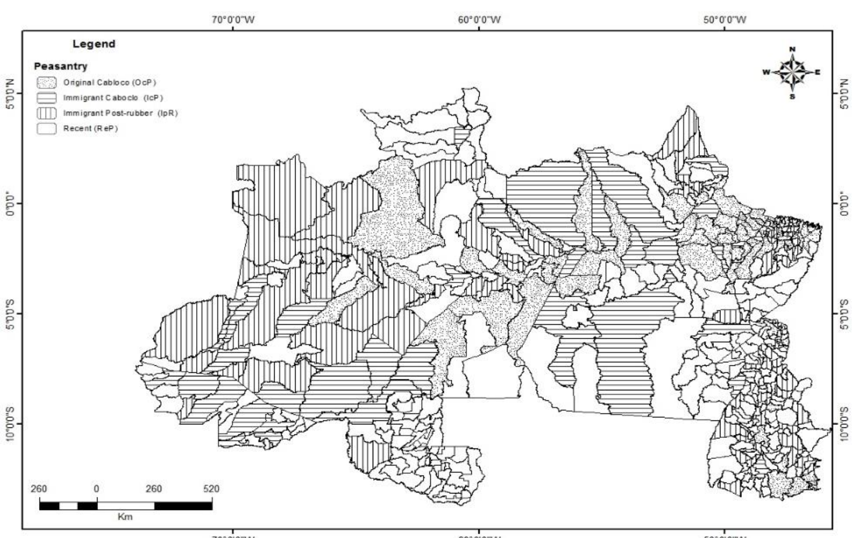
Four groups of peasants lead T2 in different territories: three historical peasantries (Costa, 2019; Nugent, 2002) and one recent peasantry ("colonist" in contrast to "caboclo", for Brondizio, 2004). As follows:

A. The historical peasants of the Amazon

a) The original caboclo peasantry (OcP)

The OcP formed from the middle of the eighteenth century, by families remaining from the religious villages. The population and defense policy of the Pombaline period stimulated the miscegenation of Portuguese and Indians, endowing the families that emerged with European knowledge, habits and needs, plus indigenous knowledge, necessary to handle the Amazonian nature. *Caboclo*, "he, who comes from the forest" in Tupi-Guarani (Lima, 1997, p. 306), of the OcP, was consolidated between 1750-1800 and was responsible for rubber production until the end of the 1870s, and remained fundamental during the rubber boom, continuing into the post-rubber era, until the present day (Costa, 2019). Its territory consists of 64 municipalities in the Brazil's Northern Region founded before 1880, from now on "Colonial Territory" (TerrCol) (see Map 1).

Map 1
The Amazonian peasantries and their territories



Source: Produced by the author. Data base: Costa (2022: *2017_NorthRegion_TechVariants.csv*).

b) The immigrant caboclo peasants (IcP)

The great *seringal mercantil* based on northeastern immigrants enabled high levels of rubber production from 1880 to 1914. With the crisis, this structure collapsed, and its rubber tappers became a new "caboclo", and because it consisted of immigrants, a "foreign" peasantry. "Caboclo" peasantry, because of living in the "bush", like its OcP counterpart, and, as time passed, based its reproduction on the forest. Being "foreign", however, knowledge of the forest was relatively topical and recent, compared to the OcP (Costa, 2019, p. 224).

The territory where the IcP was created and actually exists is basically that of the great *seringal mercantil* (TerrBorr), which today comprises 42 municipalities in the Brazil's Northern Region, established between 1880 and 1910.

c) The post-rubber immigrant agricultural peasantry (IpR)

In the post-rubber-boom period, colonization of the Santareno Plateau and Bragantina microregion, in Pará, occurred with immigrant peasants dedicated to agriculture to supply the main NR urban centers. Concurrently, from 1929, agricultural peasant nuclei were formed, made up of Japanese immigrants in the microregion of Tomé-Açu, in Santarém and Parintins. (Costa, 2019, p. 234-236).

Between 1960 and 1970, the population of the Bragantina microregion began moving towards new fronts, where the municipality of Capitão Poço gained prominence (Costa, 1996). This "immigrant-post-rubber peasantry" (IpR) constituted specific territories (TerrPBorr) in 74 municipalities of the Brazil's Northern Region founded between 1910 and 1960.

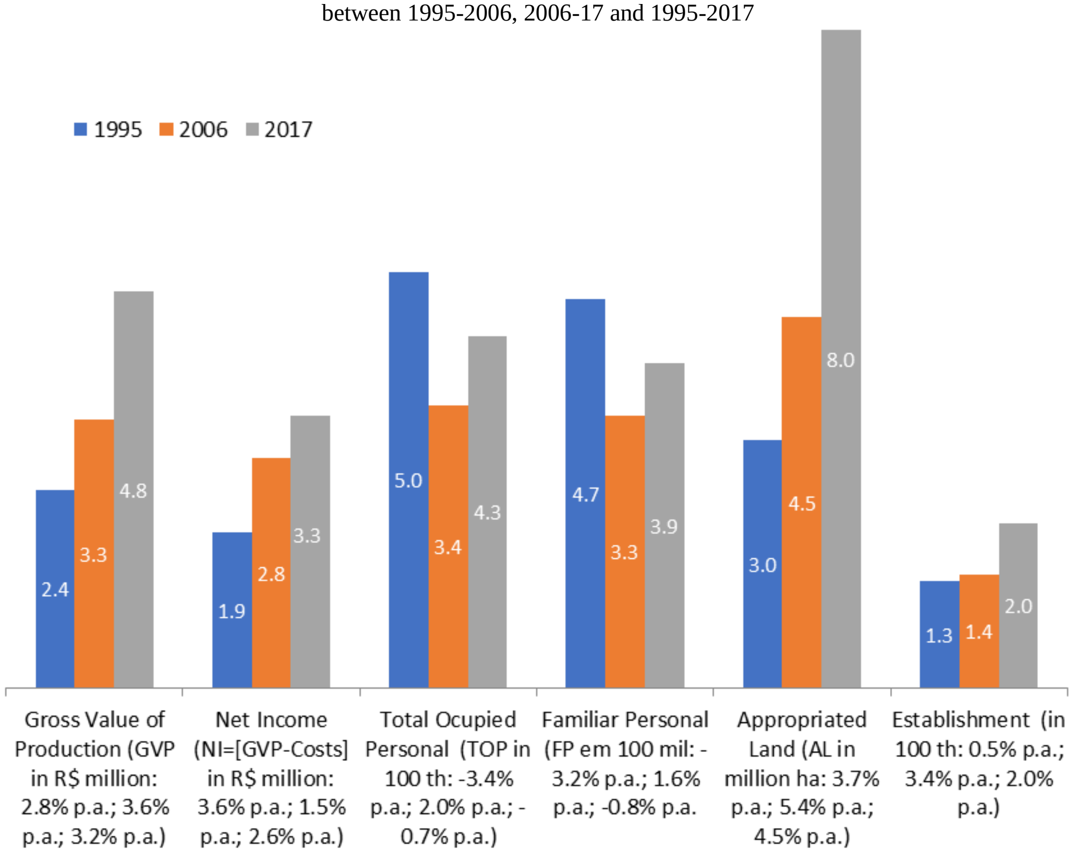
B. The recent peasantry (ReP)

The military dictatorship program for the Amazon favored the formation of peasant settlements, which had begun spontaneously with the opening of the Belém-Brasília highway from the 1950s, in areas around the Trans-Amazonian highway, in Pará, and along the BR 364 highway, in Rondônia. The term used herein for the peasantry that has formed since that time, with immigrants from all over Brazil is "recent peasantry" (ReP) and is based in the 269 municipalities founded in the region since 1960 (TerrColRec, see Map 1).

2 T2: Growth and importance

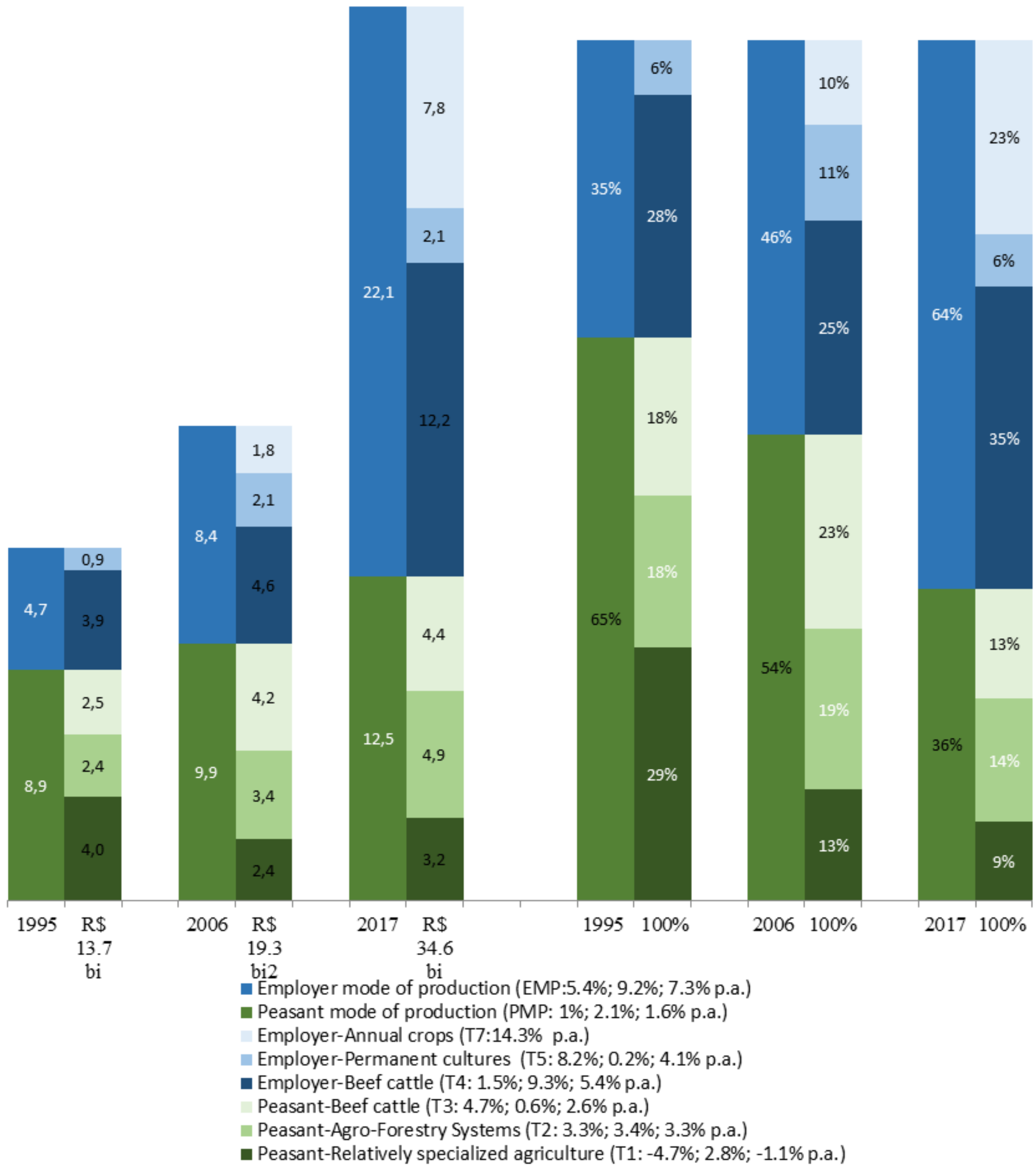
By 1995, in T2, there were 131,000 establishments, 500,000 workers (94% family members) and 3 million hectares of land; by 2017, there were 200,000 establishments, 430,000 workers (90% family members) and 8 million hectares. Generating a gross value of production (GVP) of R$ 2.4 billion in the first year and R$ 4.9 billion in the last, a growth of 3.3% p.a. occurred – the best performance amongst all the peasant trajectories (Figure 1). Even with the high growth rates of the employer trajectories, in 2017 it remained at 14% of the GVP of the Brazil's Northern Region agrarian economy – from 17.6% in 1995 and 18.6% in 2006 (Figure 2). The net income (NI), grew by 2.6% p.a., from R$ 1.9 billion to R$ 3.3 billion

Figure 1
T2 in the Brazil's Northern Region; units in parentheses on the horizontal axis, followed by the growth rates of variables between 1995-2006, 2006-17 and 1995-2017



Source: IBGE, AC (1995; 2006; 2017 and Costa (2022: *Table3_NorthRegion_T2_KeyVariables.csv*).

Figure 2
T2 in the agrarian economy of Brazil's Northern Region: % of the total GVP; in parentheses, percentages refer to the annual growth of GVP, respectively, during1995-2006, 2006-2017 and 1995-2017



Source: Costa (2021).

Techno-productive trajectories have an institutional dimension (Dosi, 1988), which is reflected in economic efficiency (Arthur, 1994). In rural areas, formal and informal institutions with access to land and biome resources, technological knowledge and financial capital are determinants for the trajectory dynamics and respective competitive capacities (Costa; Fernandes, 2016).

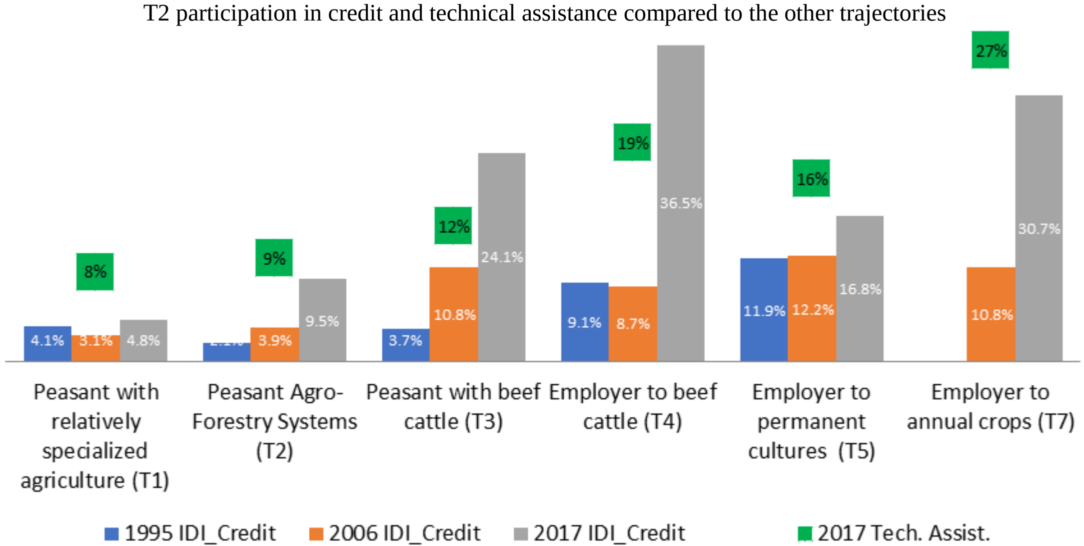
The censuses provide three indicators of T2 institutionality:

1. Land access. The land assets of the trajectory increased by 4.5% p.a. (Costa, 2020). The average size of the establishment went from 23.0 to 40.0 ha. Both figures indicate a favorable institutional environment regarding land.

2. Credit. The 9.5% share of credit in the GVP in 2017 signifies that, as a policy, T2 imported roughly 1/4 of what T4 imported and 1/3 of T7, and ½ of T3 (Figure 3).

3. Technical assistance. The proportion of establishments that received technical assistance in 2017 was 9%, the second lowest; 1/3 of the proportion of T7, ½ of T4.

Figure 3
T2 participation in credit and technical assistance compared to the other trajectories

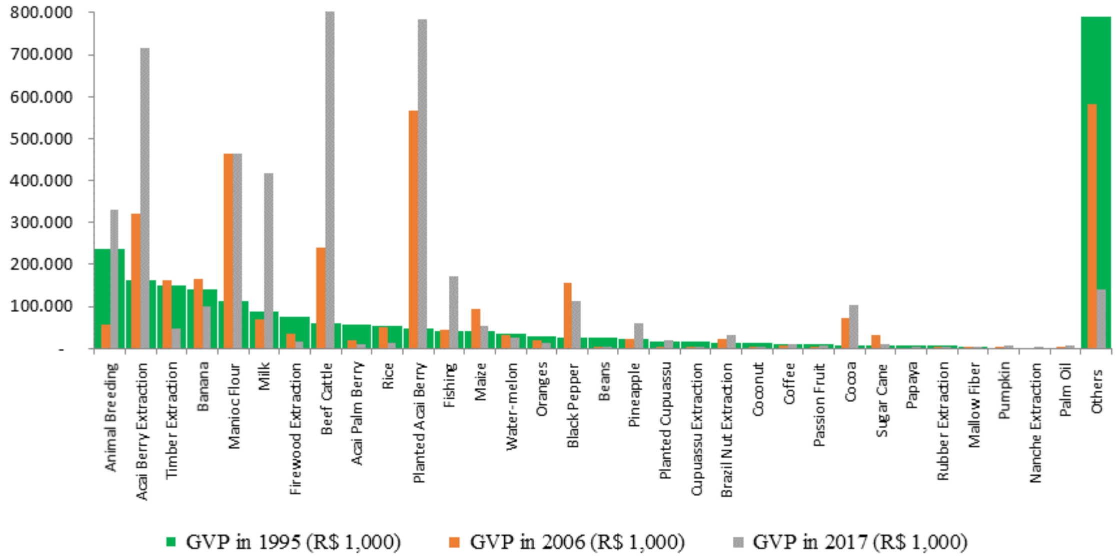


Source: IBGE, AC (1995; 2006; 2017) and Costa (2022: *Table3_NorthRegion_T2_KeyVariables.csv*).

From 1995 to 2006, growing at 2.8% p.a., T2 underwent several changes. The expansion of acai berry, both extractive and planted, was outstanding: extractive doubling the GVP (Figure 4), with production rising from 125.5 to 230.6 thousand tons; there was a 10-fold increase of GVP for planted acai based on production that increased from 39.3 to 172.8 thousand tons. This was a concomitant growth with manioc flour, whose value quadrupled with production growing from 853.3 to 1,064.4 thousand tons; in turn, the GVP and production of cattle ranching more than quadrupled. The production of black pepper increased 5-fold; palm oil 4-fold, coconut 12-fold, cocoa 6-fold. Together, these movements caused the yearly net income per family worker ($NI^*_{FW,}$ see (4)) to more than double during the period, from R$ 4 to R$ 8.3 thousand p.a. (Figure 5).

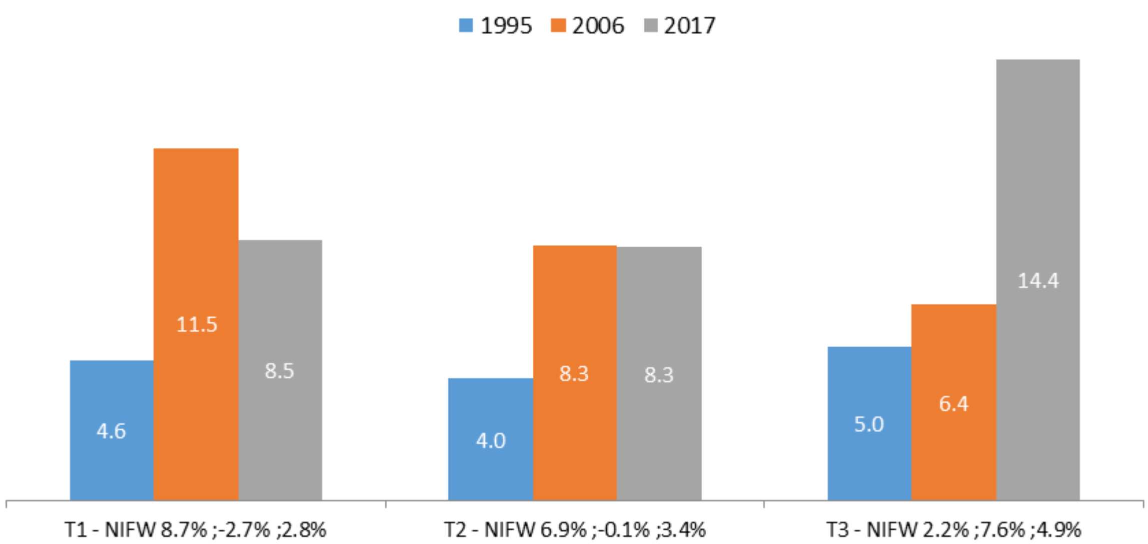
Between 2006 and 2017, the growth trends in the value of the main products continued, together with the consequent reconfiguration of the T2 production portfolio. However, there was a fundamental distinction: the NI^*_{FW} was now constant. These phenomena are detailed below, and their fundamentals clarified.

Figure 4
The composition of T2 production in 1995, 2006 and 2017



Source: IBGE, AC (2006; 2017) and Costa (2022: *Table1_NorthRegion_T2_GVP.csv*).

Figure 5
The T2 NI_{FW}^{*} in 1995, 2006 and 2017, in R$ 1,000/worker/year



Source: Costa (2020; 2022: *Table3_NorthRegion_T2_KeyVariables.csv*).

3 T2, its peasantries and technological variants: fundamentals and the evolution of production

T2 expresses the adaptive evolution of the peasant production mode within Amazonian contexts, which have enabled the establishment of lasting reproductive pattern. Depending on the prevailing territorial conditions, productive strategies were made possible for families that ultimately affirmed, through different paths, the AFS: either from managing resources originating in the Amazon biome, in a kind of "dynamic extraction" - in this case, dealing with AFSs-F; or by agricultural solutions, in successions or combinations seeking to imitate the qualities of the biome, in a kind of diverse, complex "holistic agriculture" – which are AFSs-A. The establishments in these techno-productive variants are identified in the databases used herein, according to Costa (2022: *2006_NorthRegion_TechVariants.csv* and *2017_ NorthRegion_TechVariants.csv*).

The following section presents each peasantry as part of T2: the fundamentals of production, its structure, and the aggregated results and changes in the inter-census period. Analyzing the production composition of medium establishments in the same years, microfoundations of the aggregated results are inferred and, following technological variants AFSs-F or AFSs-A, the strategies that justify them.

The original caboclo peasantry (OcP)

The OcP production in T2 consists of a wide range of 57 extractive, agricultural and livestock products and activities, whose GVP in 2006 and 2017 was R$ 1.26 and R$ 1.28 billion (Figure 6).

Acai berry and manioc flour represent an outstanding 60% of the GVP in 2006 and 63% in 2017.

Acai berry is an ancestral product of the OcP, produced by forest management and extraction. Until recently it was restricted to local markets and producer consumption. Over the last two decades however, extra local demand has grown rapidly, first in Belém, continuing the process initiated in the 1970s, and from the mid-1990s, throughout the rest of Brazil and worldwide (Brondizio, 2008; Costa et al., 2018).

As a result, extractive production intensified, and acai berry plantations emerged and expanded. In the first half of the 1990s, efforts to intensify production and the consequent increase in labor productivity were identified in açai berry extraction (Anderson; Jardim, 1989; Jardim; Anderson, 1987; Anderson et al., 1995). In turn, the OcP formation of acai berry plantations became frequent as "roçados de várzea" (floodplain plantations): "... an intensive system of combining annual, biannual and permanent crops in a space-time sequence that resembles stages of secondary succession [of the forest]" (Brondizio, 2008, p. 218). Structuring the system begins with planting short-life cycle crops alongside longer-cycle annual crops, permanent crops and forest essences. Harvesting proceeds according to the cycles. Acai berry plants begin sprouting from the beginning of the second year, protected mainly by banana trees, and from the third year, begin to dominate the landscape, producing after 3-5 years, when they reach maturity. Concomitantly, other permanent crops, such as coconut, cocoa and cupuassu start production. In the fifth year, the swidden has the structure and composition of a consolidated AFS (Brondizio, 2008, p. 218-220). Each "roça" is unique in terms of plant composition. However, the applied technological principles are similar amongst all producers (Hiraoka, 1994a; 1994b).

The 2017 census demonstrates that under OcP management, acai berry plantations measured 1.1 ha/establishment.

Manioc flour and acai berry share primacy of OcP production in T2. Manioc is grown in "roças de caboclo" (Martins, 2005): a "felling and burning" agriculture that, after using an area, is released for natural regeneration: an AFS that combines, successive agriculture and forest (Atangana et al., 2013, p. 41). Like "roças de várzea", "roças de caboclo" constitute a heterogeneous set of species, whereby patterns of composition are determined by "ecological matching skills": species with different architectures maximizing solar energy above ground, combined with species with root systems capable of exploring different soil depths, thereby maximizing water and nutrient absorption (Martins, op. cit., p. 209-210). These cycles vary, ranging from 1-3 years of planting, followed by 2-7 (or even 15) fallow years. Thus, "roças de caboclo" acquire increasingly complex secondary vegetation, which within 1-2 years obtains a structure dominated by trees (Jakovac et al., 2015; Uhl et al., 1981). On average, in the OcP, such "roças", measured 0.5 ha/establishment in 2017.

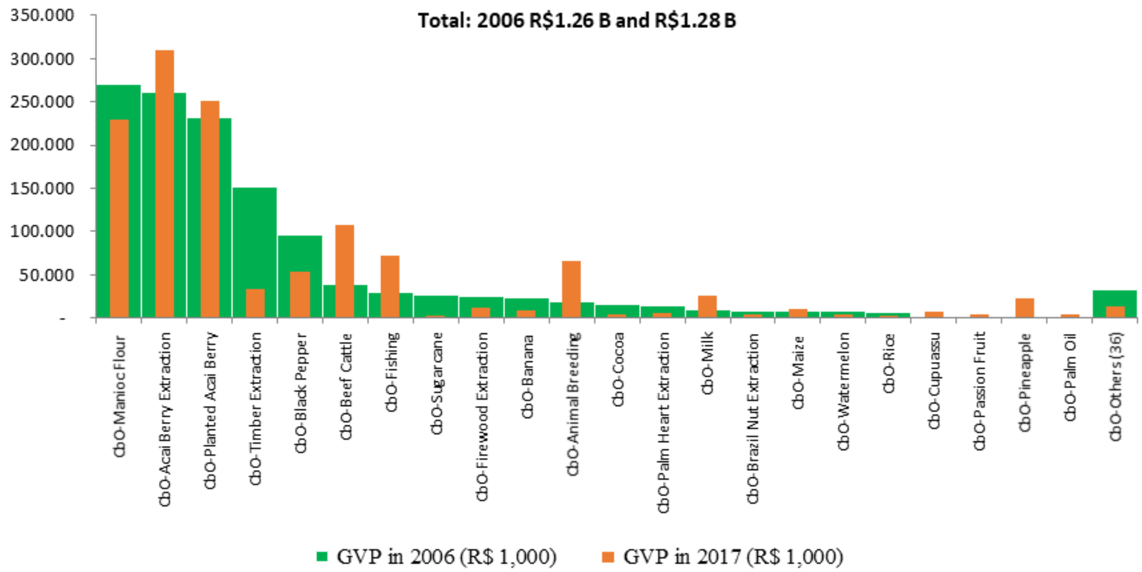
Manioc flour is processed by farmers in arrangements between neighbors and relatives (Wagley, 1988; Canto, 2007). In addition to self-consumption, flour is a commodity within different exchange circuits. The shortest occurs from the comparative advantages between the OcP lowland and upland producers, the former producing surplus acai, the latter flour (Soares; Costa, 2016). The longest reaches national markets (Salisbury; Schmink, 2007).

Changes occurred in the position of acai berry and flour in the composition of the T2 GVP in the OcP: in 2006, acai berry represented 39% and flour 21%; in 2017, acai berry grew to 44.6% (caused by a GVP increase of 4.5% p.a.), and flour fell to 18% of the total GVP (Figure 8).

Products were repositioned with a shift from producing flour to acai berry, guided by price and productivity differences of both products (Section 1, equation (4)): if $\underline{p}_{acai}.r_{acai} > \underline{p}_{flour}.r_{\underline{flour}}$ for a reasonable time, then an option for acai berry is expected. Research in Mocajuba, in TerrCol, in 2011, demonstrated that r_{acai}=3.4 t/worker/year in the OcP (Costa et al., 2022; Table1_Mocajuba_App_Work.csv); considering in 2006 $\underline{p}_{acai}$=R$ 1.48 thousand/t (Costa, 2022: *Table3_NorthRegion_T2_KeyVariables.csv*) then $\underline{p}_{acai}.r_{acai}$=R$ 5.3 thousand/worker/year; in turn, r_{flour}=1.92 t/worker/year and $\underline{p}_{flour}$=R$ 2.07 thousand/tons in 2006, so $\underline{p}_{flour}.r_{flour}$=R$ 3.98/worker/year: a 33% difference in favor of acai. In 2017, with $\underline{p}_{acai}$=R$ 2.49 and $\underline{p}_{flour}$=R$ 3.23, for constant productivity, the advantage increased to 36%.

As expected, while the quantity of produced flour decreased in the OcP between the census years to -5.3% p.a., the total production of acai berry unexpectedly decreased to -0.3% p.a. Thus, the aforementioned GVP growth of 4.5% p.a. was due to the price growth of 4.8% p.a. (Costa, 2022: *Table3_NorthRegion_T2_KeyVariables.csv*). Understanding this requires the technological variants at the establishment level to be observed.

Figure 6
T2 Production in the OcP in 2006 and 2017



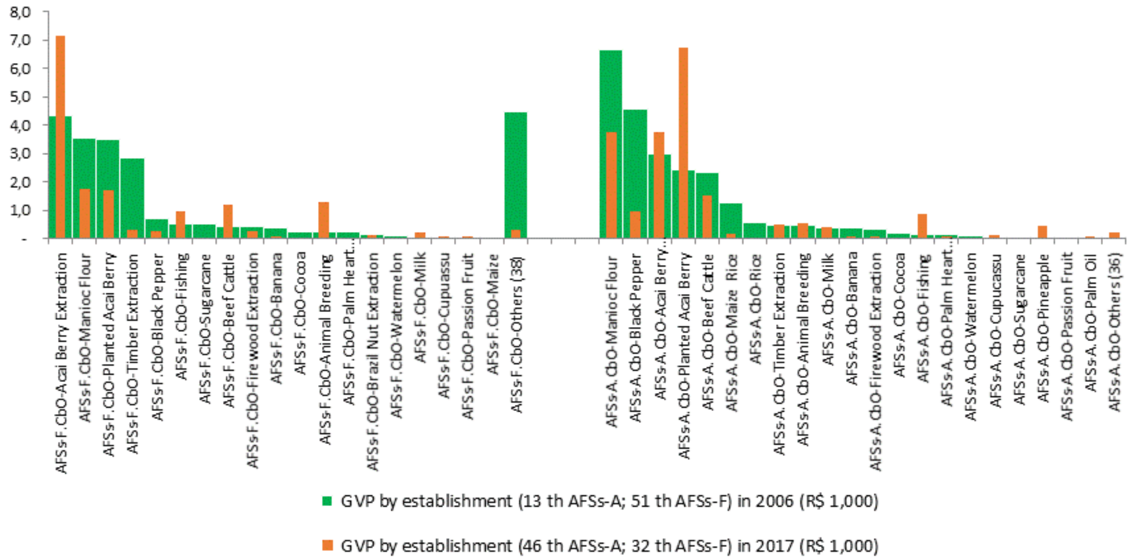
Source: IBGE, AC (2006; 2017) and Costa (2022: *Table1_NorthRegion_T2_GVP.csv*).

The technical basis for acai berry production in T2 in the OcP changed: in 2006, production came predominantly from AFSs-F variant establishments, whereby the 51,000 establishments were responsible for 82% of production; only 12%, therefore, came from the 13,000 AFSs-A variant establishments (Figure 7).

In the inter-census period, 19,000 establishments moved from AFSs-F to AFSs-A. Concomitantly, the average production of acai berry in the AFSs-A establishments grew from 2.8 to 3.8 tyear (Costa, 2022: *Table3_NorthRegion_T2_KeyVariables.csv*). In 2017, in the AFSs-F variant, 32,000 establishments remained, where average acai berry production fell from 5.5 to 4.2 tyear. This change was responsible for the reduction of 149,000 tons in acai production, which, greater than the 137,000 ton increase verified in the AFSs-A, led to the abovementioned reduction of total T2 acai berry production in the OcP.

In 2017, flour production at the average AFSs-A establishment fell to approximately 1/3 of 2006; in AFSs-F, the reduction was greater, to approximately 1/5.

Figure 7
The GVP composition of the T2 average establishment in the OcP, 2006 and 2017.



Source: IBGE, AC (2006; 2017). Costa (2022: *Table1_NorthRegion_T2_GVP.csv*).

Thus, related to its main products, there were three processes in the OcP within the context of T2: 1) in the AFSs-A variant, acai berry partially replaced flour in the production composition of the medium establishment; 2) competition between the technological variants where planted acai berry replaced extractive acai berry determined the expansion of the AFSs-A variant to the detriment of AFSs-F; 3) concurrently, AFSs-F production of acai berry and flour decreased significantly in the medium establishment, despite rising prices for both products.

This latter process is explained by constrained resources or by behaviors that generated "inverted supply" (see Section 1).

On resource constraints:

1. The availability of land affecting productivity. The OcP represented the smallest land endowments for the T2 establishment, probably because it was the oldest Amazonian colonization territory. The average 21.5 ha lot of AFSs-F, in 2006, the smallest in T2, reduced to 16.8 ha in 2017. For an AFSs-F-based economy, this was probably a significant constraint, negatively affecting work productivity in extraction and management. It may also have been a restriction for implanting acai berry "roçados de várzea".

2. Reductions in available work. In 2006, the AFSs-F establishments presented on average, 2.5 worker-equivalent, which dropped to 2.1 in 2017. If this resulted from the average aging of families, there would be a fundamental limitation (Costa, 2022: *Table3_NorthRegion_T2_KeyVariables.csv*).

3. Countercyclical behavior generates an "inverted supply", which is the general designation for situations where families perceive reproductive efficiency advantages in reducing

production of a certain product when prices are higher, proportionally equal to or less than the price growth. There are several justifications for this in RE-based economies, all associated with what is done with the time saved. First, it is commonly stated that this behavior results in a preference for the leisure of a drudgery-averse peasant (Ellis, 1988: 102-119), although there are no empirical elements to verify whether this is present in the studied reality. Other possibilities, however, associated with productive investments or changes in the reproductive pattern, are discussed below:

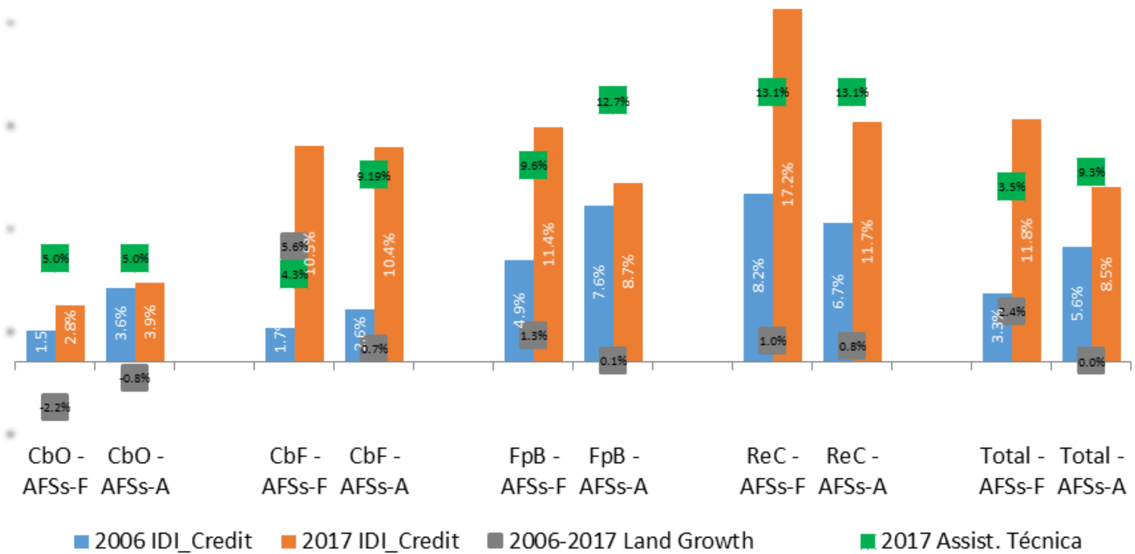
a. *Investments with the direct use of saved labor*. Various activities and products in the OcP AFSs-F grew in importance, requiring investments from families, probably with the direct use of labor which, with the appreciation of acai, became amenable to application for this purpose. Investments such as "productive self-consumption" are all the more plausible, on recognizing that only 1.5% and 2.8% of the OcP AFSs-F GVP was obtained with credit assistance (the lowest level across the whole T2, conf. Figure 8).

b. For establishments with land restrictions, it is reasonable to expect investments in activities that dispense with or minimize land. This is compatible with the growth in small animal breeding, which grew in the AFSs-F establishments from 1% to 8% of the average GVP; and fishing from 2% to 6%. Fishing is a basic activity amongst caboclo peasants and with acai and flour, forms the local "tocantina" diet (Roggé, 2002). It is important for self-consumption (Cerdeiro; Rufino, 1997) and as merchandise (Furtado, 1993; Canto, 2007). In 2011, in Mocajuba, in TerrCol, 31% was for self-consumption (Costa et al., 2022: *Table7_Mocajuba_GVP_SelfConsum.csv* and *Table5_Mocajuba_GVP_Total.csv*).

c. For establishments with work restrictions and land surplus, investment in labor-saving and more demanding land activities, such as cattle ranching, is expected. Beef cattle in the reproductive pattern of caboclo peasants in the middle to low Amazon dates back to the eighteenth and nineteenth centuries (Harris, 1998; Nugent, 2002; Folhes, 2018), under different conditions: as a current liquidity commodity, or contingency reserve or as savings for future plans (Canto, 2007; McGrath, Almeida, Mery, 2007). In turn, dairy cattle is important for direct supply, demonstrating high self-consumption (in the OcP as a whole, 80% in 2006 and 73% in 2017). In the average establishment in OcP AFSs-F the value of livestock products increased from 2% to 7% of the GVP (Costa, 2022: *Table3_NorthRegion_T2_KeyVariables.csv*).

4. Topic 2 above, reported a reduction in the average number of worker-equivalent in the average family. If this resulted from a strategic change in the application of its members, with displacements to urban centers with a view to education, there is a fundamental change in the reproductive pattern to justify this behavior.

Figure 8
Indicators of institutional conditions for access to land, credit, and technical assistance in relation to peasantries and technological variants, 2006 and 2017



Source: IBGE, AC (2006; 2017) and Costa (2022: *Table3_NorthRegion_T2_KeyVariables.csv*).

The immigrant caboclo peasantry (IcP)

The T2 portfolio of products and activities in the IcP and its variations present similarities to T2 in the OcP: manioc flour and acai berry appear as the main products, whereby the relative importance of acai berry grew and that of flour dropped; cattle raising, fishing and animal breeding also grew in importance, as in the OcP, with many extractive and agricultural products (Figure 9).

Such similarities indicate common foundations, particularly the condition of caboclo peasantry, with its long-accumulated learning processes linked to the original nature and the associated technical repertoires. Certain differences exist however, that indicate dissociations from evolutionary paths or complementarities associated with specific territorial contexts – natural and institutional.

Production growth and composition are distinguished mainly in relation to the rhythms and fundamentals in the growth of acai berry; the relationships between the growth of acai berry and manioc flour and the extent of the growth of cattle ranching.

Rhythms and fundamentals of the growth of acai berry. The acai berry GVP grew faster in the IcP than in the OcP, respectively, at 6.9% and 4.5% p.a., mainly due to producing a greater quantity, 6.3%, which, in turn, resulted from an increase in extractive production to 16.7%, since the production of planted acai berry fell to -1.8% p.a. – precisely the inverse of the OcP, where extractive production fell by -0.7% and planted production grew by 0.2% p.a. Notwithstanding, growth in total production resulted from production growth in both variants: 4.9% p.a. in AFSs-A; 8.6% p.a in AFSs-F. (Figure 10; Costa, 2022: *Table3_NorthRegion_T2_KeyVariables.csv*).

These results indicate that in the IcP the expansion areas of extractive acai production were established. The municipalities of Pará in the IcP, contiguous to the municipalities of the OcP, behaved as follows: Afuá extracted 4,000 tons in 2006 and 39.4 thousand tons in 2017; Barcarena went from 2.4, to 16 thousand; Limoeiro do Ajuru, from 2.4 to 20 thousand. There, the number of establishments and workers increased correspondingly: Afuá, from 1,983 establishments and 2,719 workers to 4,122 and 7,967; Barcarena from 815 and 2,415 to 2,953 and 5,520; Limoeiro do Ajuru, from 2,589 and 5,362 to 3,514 and 8,095.

The expansion of acai berry in the IcP and the prevalence of AFSs-F were driven by price differentials paid to producers and their own institutional conditions. In effect, the implicit price in the IcP was 70% higher than that of the OcP in 2006. Moreover, the difference in the implicit price in the AFSs-F variant of the former compared to the latter was even higher, at 90% (Costa, 2022: *Table3_NorthRegion_T2_KeyVariables.csv*). In turn, institutional conditions were different in the IcP, compared to the OcP, especially regarding AFSs-F. In terms of land area, an increase occurred in the number of establishments and in the average size of the AFSs-F, at 5.6% p.a. (in AFSs-A at 0.7%), where the credit share in the GVP jumped from 1.7% in 2006 to 10.5% in 2017 (as in AFSs-A). During this year, 4.3% of its establishments received technical assistance (in AFSs-A 9.1%) (Figure 8).

The acai berry-manioc flour relationship. The price differentials, on the other hand, in the IcP, raised the comparative advantage of acai berry over flour, so that the production of flour was reduced by half, as a result of the propensities in force in the establishments, particularly in the AFSs-F variant: here, while acai berry production increased from 2.5 to 5.2 tyear, flour production decreased from 1.9 to 0.5 tyear.

The growth of cattle ranching. A remarkable phenomenon in the IcP: beef production increased from 4.4% to 17.2% and milk from 1.3% to 3% of the GVP.

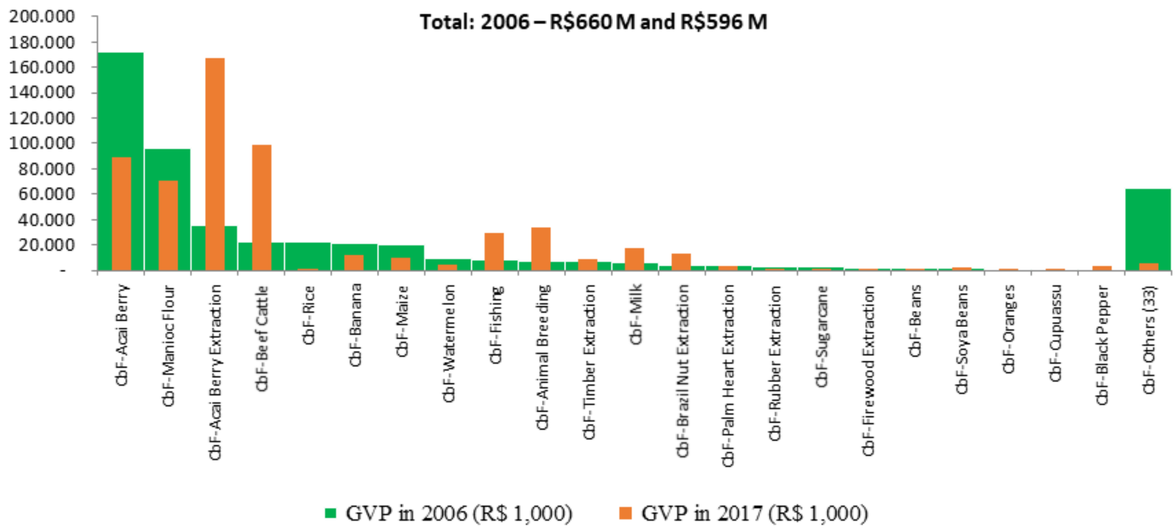
The phenomenon was more significant in AFSs-F and already visible in the 2006 census in the IcP. Sulisbury and Schmink (2007) analyzed its emergence in Acre because of the final crisis of the region's extractive rubber economy caused by the total withdrawal of government subsidies in the early 1990s. From then on, the process changed, marked by the extractive peasants in Acre diversifying their production. Searching for alternatives first led to planting manioc and producing flour as a substitute commodity for rubber. In subsequent changes, more pronounced throughout the 2000s, there was increased investment in cattle and permanent crops. Here, the role of credit was highlighted.

In the 2006 Census, 3,540, or 19% of T2 establishments in the IcP, included cattle ranching in their production systems, producing meat and milk. In 2017, 6,725 (26%) of these establishments presented these characteristics. The average size of pasture per establishment went from 15 to 40 ha and the number of heads from 69 to 57, reducing the intensity to 1.4 heads/ha.

Cattle raising in the IcP was present in several different places: just over 1,000 establishments in Pará, mainly in Almeirim, where in 2017, beef cattle represented 24% of the GVP, along with non-timber extraction, with 29%; it grew particularly fast in the municipality of Amapá, where it represented 20% of the GVP in 2006, rising to 63% in 2017. However, it was particularly high in

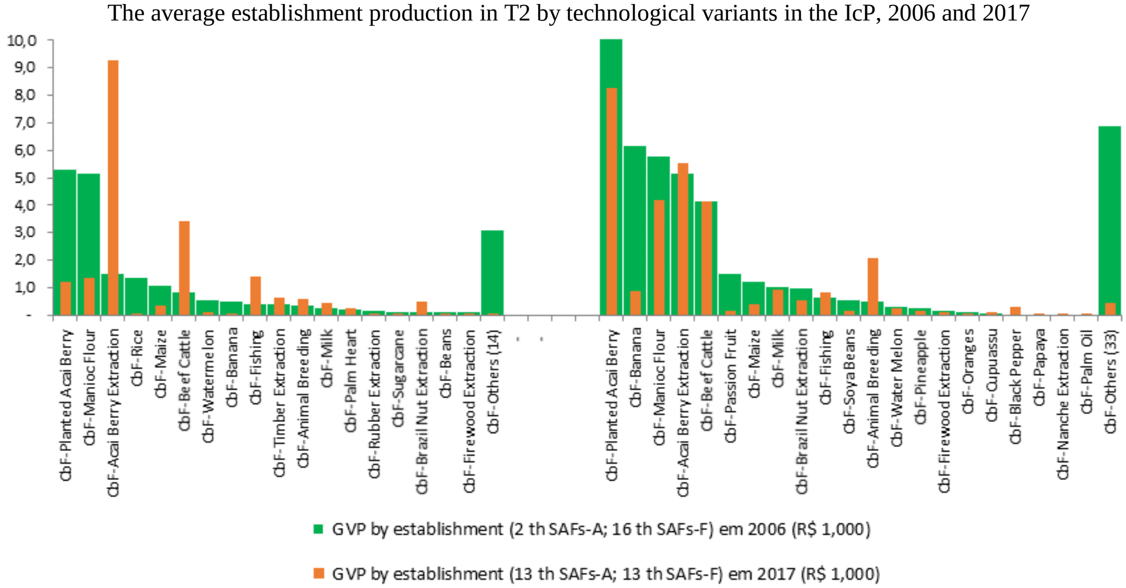
Acre, where 4,771 (71%) of T2 establishments in the IcP presented these characteristics, whereby the trend sharpened: on the municipality of Assis Brasil, it was 30% in 2006 increasing to 51% in 2017; in Xapuri, from 6.2% to 48.3%; and in Sena Madureira in 2017 to 53.7%.

Figure 9
The T2 GVP in the IcP, 2006 and 2017



Source: IBGE, AC (2006; 20170) and Costa (2022: *Table1_NorthRegion_T2_GVP.csv*).

Figure 10
The average establishment production in T2 by technological variants in the IcP, 2006 and 2017



Source: IBGE, AC (2006; 2017) and Costa (2022: *Table1_NorthRegion_T2_GVP.csv*).

The post-rubber immigrant peasantry (IpR)

In the OcP and IcP, we addressed peasants with a long-term extractive tradition in the Amazon, into which, however, agricultural solutions have imposed themselves in the AFSs-A technological variant that replaced the AFSs-F variant. The variants are concurrent and, depending on the institutional and natural conditions in force within the territories, one or the other prevails. For example, with the increasingly important role of acai berry in T2, in the OcP, the AFSs-A variant tended to dominate; in the IcP, it was the AFSs-F. However, these variants are of the same technical culture, that of the caboclo peasants in the Amazon, "Masters of Forestry". Hence, the OcP and IcP were responsible for 86% of the GVP of non-timber extractive products in the entire Brazil's Northern Region: specifically, 100% of palm heart produced, 92% of nanche, 85% of bacuri, 79% of andiroba, 73% of rubber, 67% of acai berry; 67% of firewood, 65% of extractive cupuassu, 63% of extractive cocoa, and 61% of Brazil nuts (Costa, 2022: *Table3_NorthRegion_T2_RealProduct.csv*).

The IpR presents a different situation, where caboclo peasants operate in AFSs-F, and agricultural immigrant peasants in AFSs-A.

In 2006, there were 15,000 establishments in the AFSs-F variant in the IpR in 19 municipalities. Outstanding are Coari and Anori, in Amazonas, Bujaru, Inhangapi and Mãe do Rio, in Pará (Map 2). As in the OcP and IcP, manioc flour, with 18% of the GVP, and extractive acai, with 10% of the total GVP, were the main products, alongside other vegetal extractive products such as firewood (4% of GVP), Brazil nuts (2%) and cupuassu (1%). Beef cattle appeared with 7% and milk 3% of the GVP; fishing and farming were 2%; and annual maize crops (9%), rice (4%), watermelon (4%), pineapple (3%) and beans (1%) were cultivated. Permanent crops such as bananas (7%) acai berry (3%) and oranges (2%) may be regarded as tests to the presence of cupuassu, coconut, black pepper and cocoa (Figure 11).

In 2017, the number of establishments in this variant reduced to 8,000 and the structure of the production value changed significantly. The most notable differences were a reduced GVP of manioc flour to -7% p.a. (finally representing 11.5% of the total value), an increase in the value of beef cattle to 3.1% p.a. (reaching 32%); an increase in acai berry to 1.2% p.a. (raising its relative share to 11%). Considering the price movement of the abovementioned products for the AFSs-F establishments in the IpR, these values correspond to significant reductions in the physical scale of the establishments. Indeed, with the price of flour growing at 5.3% p.a., the quantity produced was drastically reduced to -14.5 p.a.; with the price of acai berry increasing at 9.1%, production decreased by -7.2% p.a.; with the price of cattle growing by 3%, the number of slaughtered animals remained practically constant (Costa, 2022: *Table3_NorthRegion_T2_KeyVariables.csv*). Given that no activity emerged, it seemed to be facing a divestment route.

This fraction of caboclo peasants lives with the foreign peasantry of the AFSs-A variant, which settled in the Amazon after the rubber boom and is characterized by a long regional agricultural experience. By creating and managing AFSs, its participation in T2 occurred after the intense agricultural use of its territories, in the context of the colonization experiences of Northeastern Pará, from the end of the nineteenth century, and of Japanese colonization after the 1920s.

The peasantry that formed in Bragantina and extended into Guajarina basically produced rice, beans, manioc, and corn, in shifting cultivation. A profitability crisis appeared in the late 1970s, which extended into the 1980s. In response, there was a trend towards diversification by introducing permanent cultures, in an intensification route type I (see section 1 and Costa, 2012b, p. 171-173). This was particularly intense in Capitão Poço, where, between 1970 and 1993, 31 permanent cultures were introduced, in different consortia, emphasizing compositions of orange, passion fruit and black pepper, almost always integrated with temporary cultures and other less frequent permanent cultures (Costa, 1996).

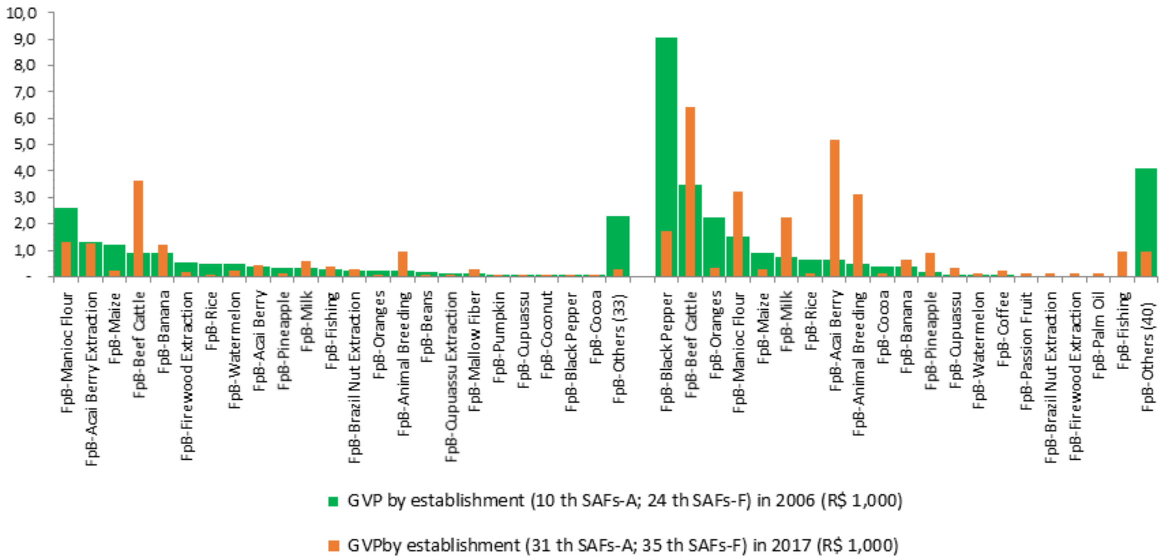
In a comprehensive survey on Amazonian AFSs, Smith et al. (1996, p. 18-19) confirmed the importance of this experience, citing that experiments in Capitão Poço were responsible for some of the most frequent AFSs observed.

Part of the innovations in Capitão Poço was, in turn, due to innovations by Japanese settlers in Tomé-Açú. First, Japanese colonization introduced new cultures such as jute, in Parintins, Amazonas, and black pepper, in Tomé-Açú, Pará (Homma, 2007), which developed throughout the 1940s/50s, experiencing a peak in the 1960s. In the following decade, black pepper suffered a severe crisis, when fusariosis drastically reduced the life cycle of monocultures from 15 to 5 years (Yamada, Osaqui, 2006, p. 312). The Japanese colony in Tomé-Açú and underlying areas replaced black pepper with diversified fruit, increasingly in AFSs-A. Yamada and Osaqui (2006, p. 311-312) reported movements amongst pioneer families testing different paths and sharing results to form a local innovation system, which until the second half of the 1990s generated 300 polyculture combinations using 70 different species (Yamada, 1999). Researchers described the Tomé-Açú establishments composing an irregular landscape, where species of different ages were present in a variety of combinations. It was emphasized that the sequences of cultures were similar to the natural succession of the biome, moving from the herbaceous to arboreal stages and allowing the permanent use of agricultural fields (Subler; Uhl, 1990; Serrão; Homma, 1993; Subler 1993). One of these systems, investigated by Yamada (1999), rigorously imitated an advanced stage of forest succession, producing 250 metric tonsha of biomass – no less than 2/3 of primary forest production in the same region (Teixeira et al., 1994).

The T2 AFSs-A establishments in the IpR totaled 6,500 in 2006, in nine municipalities, including Tomé-Açú and Capitão Poço, in Pará, and Silves in Amazonas (Map 2). The GVP composition of the average establishment highlighted permanent crops such as black pepper (36% of the total GVP), combined with orange (9%), planted acai berry (3%), cocoa (2%), banana (2%), cupuassu (1%) and coffee (1%); and incorporating manioc flour (6%), corn (4%) and rice (3%), alongside small animal husbandry (3%) (Figure 11).

In 2017, the number of establishments doubled, and the production composition changed: in the main core, there was a reduction of black pepper (to 6% of GVP) and orange (to 1%). In contrast, beef cattle, with 24% of the GVP, assumed the main position; planted acai berry increased to 19%; and flour reached 12%. All of these in direct correlation with the price and quantity, which grew, respectively, at 5.7% and 10.5%; at 17.6% and 18.3 and at 4.6% and 11.9%.

Figure 11
Production by the average establishment of the technological variants of T2 in the IpR in 2006 and 2017



Source: IBGE, AC (2006; 2017) and Costa (2022: *Table1_NorthRegion_T2_GVP.csv*).

The recent immigrant peasantry (ReP)

Contrary to the other T2 territories, in which different historical peasantries dominated, the ReP is composed of recently-arrived immigrant farmers through colonization projects directed towards Trans-Amazonia and Rondônia, or even as part of the spontaneous agricultural frontier in Southeast Pará.

In Trans-Amazonia and Rondônia, scripts were developed like those reported in the IpR, with equivalent outcomes. During the 1970s, the first decade of colonization, the main product amongst farmers in Trans-Amazonia and Rondônia was a monoculture of rice. Rapid depletion of the soil by leaching led to the first productivity crisis (Smith, 1978). In the 1970s and early 1980s, federal government agencies CEPLAC and EMBRAPA promoted cocoa and coffee monocultures in these areas, replacing rice (Mendes, 2005). At the end of the 1980s, a new crisis occurred, caused by a sharp fall in the prices of these commodities.

Smith et al. (1996) observed three paths following from there: the abandonment of monocultures, or maintaining very few, in the expectation of an increase in prices; crop substitution for something more promising or for pasture and cattle and, finally, a third path followed by many: a consortium of cocoa or coffee with other perennials, in AFSs. Thus, a variety of systems developed involving cocoa and coffee, associated with fruit, such as acai berry, biribá, pineapple and tangerine, or with timber, such as mahogany, cedar, freijo, ipe and cuiabano pine.

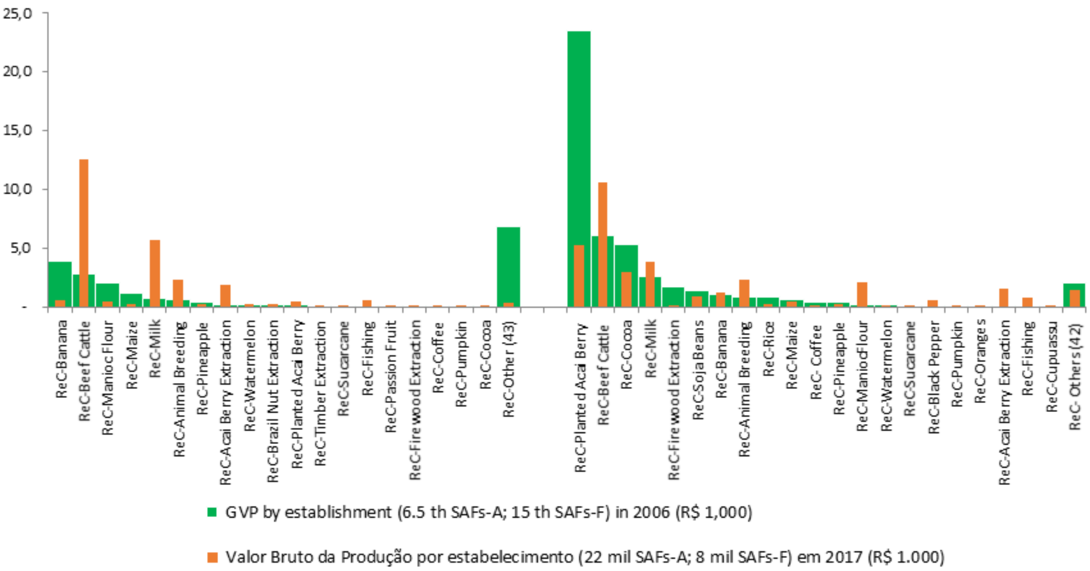
The T2 AFSs-A variant in the ReP, distinguished in the 2006 and 2017 censuses in Medicilândia and Senador José Porfírio, in Trans-Amazonia, and Santa Luzia d'Oeste, Costa Marques, Teixeirópolis, Cacaulândia and Vilhena, in Rondônia, are expressions of these developments (Map 2). In 2006, 6,500 establishments existed, highlighting planted acai berry (50% of the GVP), cocoa (11%), banana (2%) and coffee (1%) and pineapple (1%), combined with rice, corn, livestock, beef cattle (13%) and milk (5%). In 2017, there were 22,000 establishments. They reduced the importance of planted acai berry and cocoa to 15% and 8%, respectively; on the other hand, beef cattle grew to 30% of GVP and milk, to 11%, flour (to 6%), acai berry extraction (to 2%), banana (to 4%), black pepper (to 1%) and fishing (to 2%) (Figure 12).

Changes in the ReP AFSs-A were favored by institutional conditions that enabled the growth of the size of the lots, a proportion of credit in the GVP of 11.7% and a portion of those who received technical assistance of 13.1% (these are positively differentiated proportions in T2).

Areas of the spontaneous agricultural frontier also belong to the ReP, or have been induced by the formation of infrastructure, such as, in Southeast Pará, Parauapebas and Nova Ipixuna (Costa et al., 2013), where large native formations existed of acai berry, Brazil nuts, or other products of the biome that, through market valuation, were incorporated into the production systems. This was also the case of Laranjal do Jari, in Amapá, or Amaturá, in Amazonas. The T2 AFSs-F variant in ReP evolved in these locations (Map 2). In 2006, 15,000 establishments predominantly comprised agricultural systems (banana 20% of the GVP per establishment, flour 10% and corn 6%), combined with significant beef cattle and milk production (respectively, 14% and 4% of the average GVP) with modest participation in acai berry extraction (1%) and Brazil nuts (0.2%) and several other products. In 2017, the establishments in this variant decreased to 8,000. In turn, beef cattle increased to 48% of the average establishment GVP, milk to 22%, poultry and small animal breeding to 9%, fishing to 2% and, most distinguishable, extractive acai berry production to 7% and Brazil nuts to 0.3%. Such changes, particularly the strong increase in livestock, were favored by the growth in the average size of the establishment and by the significant participation of credit in the GVP, of 17.2% and the correlated participation in technical assistance services.

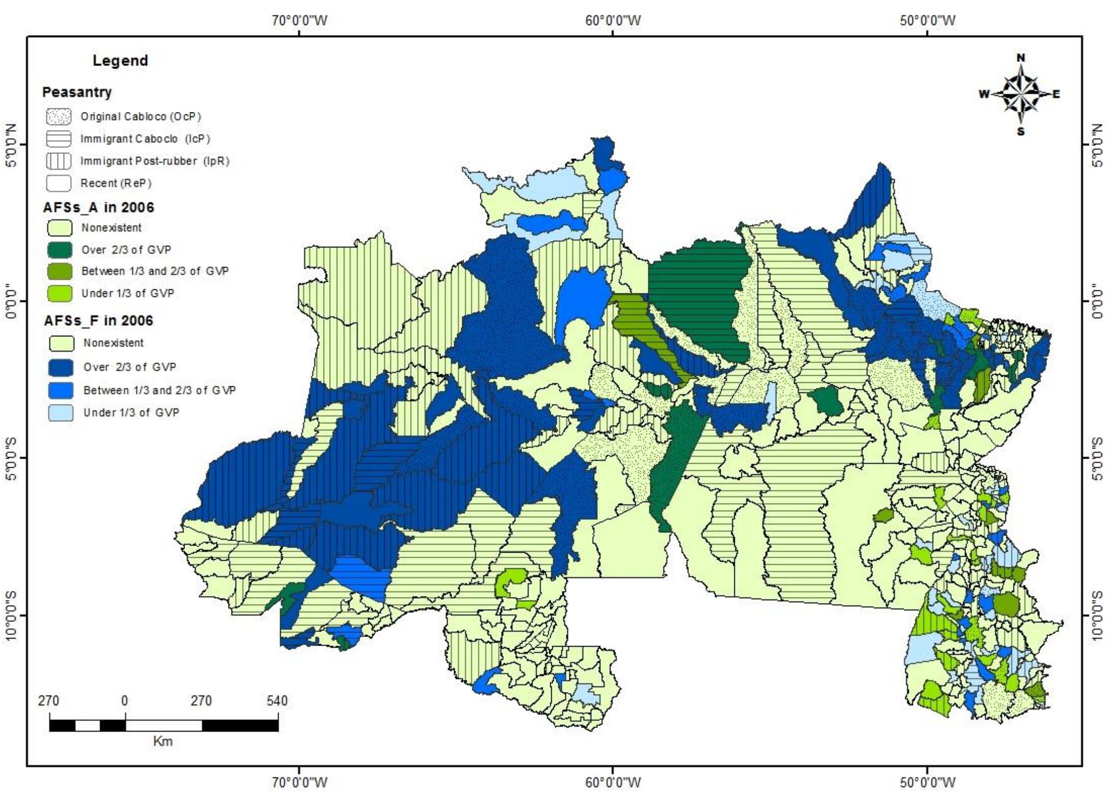
Notwithstanding, the new levels of livestock components in 2017 in the ReP AFSs-F accounted for high portions of T2 extractive production: 27% of the acai production, 55% of buriti, 48% of pupunha, 30% of cocoa, 23% of Brazil nuts, 22% of bacaba, 22% of rubber, 19% of cupuassu (Costa, 2022a: *Table3_NorthRegion_T2_RealProduct.csv*).

Figure 12
Production by the T2 average establishment on technological variants in the ReP, 2006 and 2017



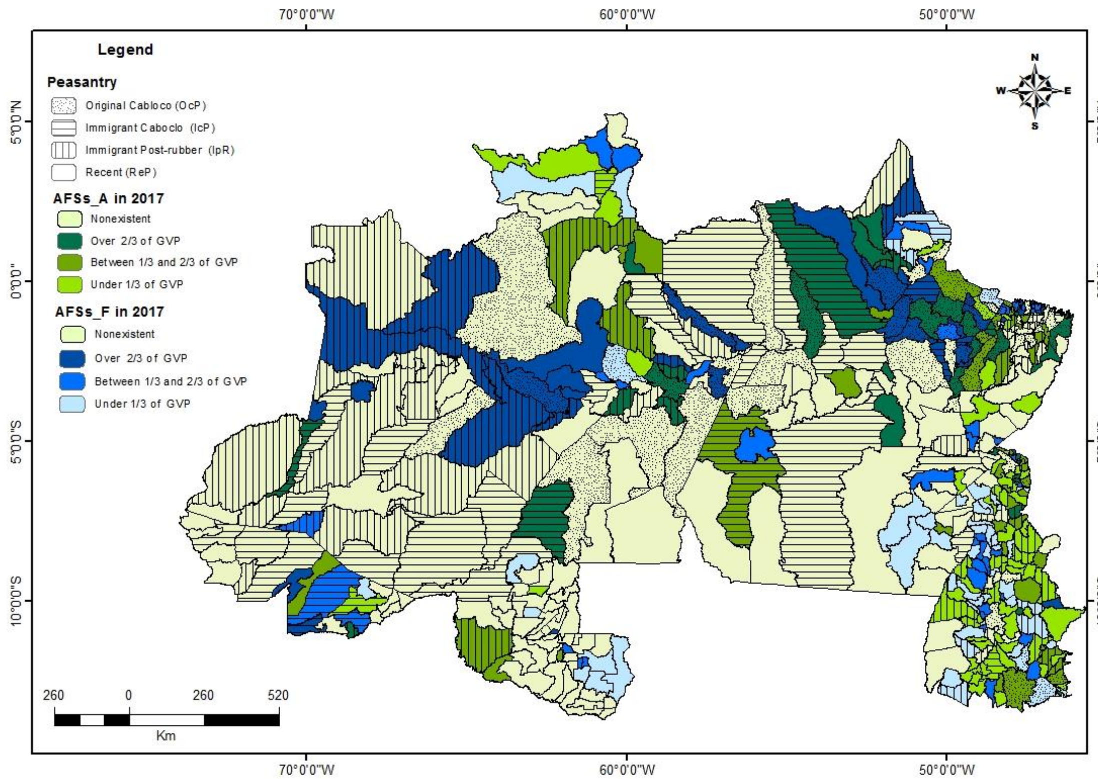
Source: IBGE, AC (2006; 2017) and Costa (2022: *Table1_NorthRegion_T2_GVP.csv*).

Map 2
Territorial distribution of T2 technological variants, 2006



Source: IBGE, AC (2006) and Costa (2022: *2006_NorthRegion_TechVariants.csv*).

Map 3
Territorial distribution of T2 technological variants, 2017



Source: IBGE, AC (2017) and Costa (2022: *2006_NorthRegion_TechVariants.csv*).

4 T2 developments and economic efficiency indicators

Based on the structures of production in the territories, changes were analyzed as a result of decision-making processes at the establishment level: focusing on portfolios of products and activities, scrutinizing the dynamic interactions between them and between them and the natural, institutional and market context. It is now necessary to verify the coherence and consistency of the results of that dynamic in the entire T2 economy.

To do so, it is necessary to check two things. First, whether the variations observed in the net income from family work (NI^{*}_{FW}), resulting from the choices of the peasant families that we analyzed before, justify the changes in the structuring of T2, whether in terms of its technological variants or in terms of territories where they operate. The aim is to verify in section 4.1 whether the processes that resulted in the productive conformation of each territory through competition between the technological variants SAFs-F and SAFs-A of the T2 trajectory are path-efficient: with Arthur (1994: 13-32), it is understood that the consistency of a trajectory emerge from the cumulative results of path-efficient decisions, whereby, at any time *t*, if there are two technological variants, SAFs-F and SAFs-A, for example, a choice for SAFs-A, which is established in variant *m* with payoff NI^{*}_{FW}SAFs-

A(m), while the SAFs-F variant is located in variant k<m, will be done while NI_{FW}^{*}SAFs-A(m) ≥ Maxj {NI_{FW}^{*}SAFs-F(j)} para k ≤ j ≤ m.

Second, in following section 4.2 the determinants of the changes will be verified to inquire about the sustainability of the observed routes.

4.1 Variations in NI_{FW}^{*} and technological and territorial changes in T2

In 1995, the T2 NI_{FW}^{*} in the Brazil's Northern Region, of R$ 4.0 thousand worker/year, was the lowest of all peasant trajectories. In 2006, this more than doubled and in 2017 remained at a level of R$ 8.3 thousand (Figure 5). The intense movement observed in Section 3 closes the structural "history" of this maintenance, which was based on considerable differences in structural components and resulted from significant changes in these differences. The following items emerge:

1. There are notable differences between the NI_{FW}^{*} of the technological variants in T2: the AFSs-A, in 2006, was 61.6% higher than that of AFSs-F; in 2017, the difference grew to 63.5%. The result was an inversion of the productive base of the trajectory: in 2006, AFSs-A represented 32% of the production; in 2017, 63%; AFSs-F, in turn, was 68% and 47% (Figures 13 and 14).

2. The behavior of the variants was successively different from territory to territory.

   a. In the OcP, the AFSs-A NI_{FW}^{*} in 2006 was slightly lower than that of AFSs-F and remained the same in 2017. However, the AFSs-F NI_{FW}^{*} fell significantly, causing shifts in the AFSs-A variant, which grew from 9% to 20% of the T2 production there. The AFSs-F, in turn, fell from 36% to 11%. The OcP NI_{FW}^{*} fell significantly, as did its share in T2, which dropped from 45% to 31%.

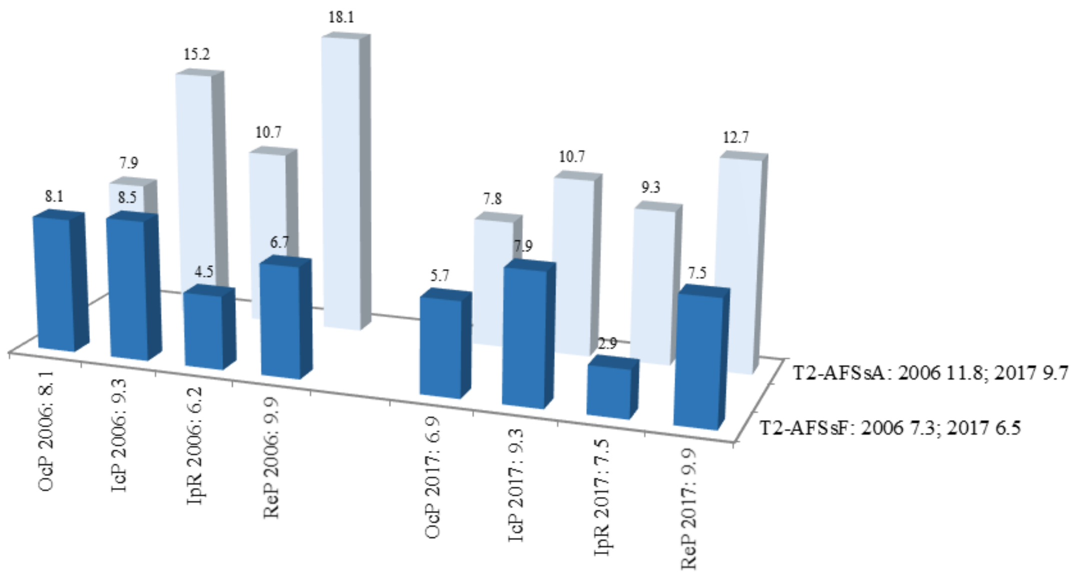
   b. In the IcP, the NI_{FW}^{*} of AFSs-A was consistently higher than that of AFSs-F, although with a decreasing tendency. The result of the former increased, from 3% to 8%, and the latter decreased, from 11% to 6%. As the NI_{FW}^{*} of the territory, the participation in T2 remained at the level of 2006 (14%).

   c. In the IpR, with the AFSs-A NI_{FW}^{*} consistently high and that of AFSs-F on the decrease, the importance of the former grew from 6% to 13% and the latter fell from 6% to 2%. With the average NI_{FW}^{*}, the share of the territory increased from 12% to 14% of T2.

   d. The highest NI_{FW}^{*} of AFSs-A occurred in the ReP; meanwhile, the NI_{FW}^{*} of AFSs-F also grew. As a result, both the importance within AFSs-A and that of AFSs-F grew, respectively, from 14% to 23% and from 15% to 19% of T2.

Figure 13
The NI_{FW}^{*} of the T2 peasantries and technological variants, 2006 and 2017, at R $ 1,000year

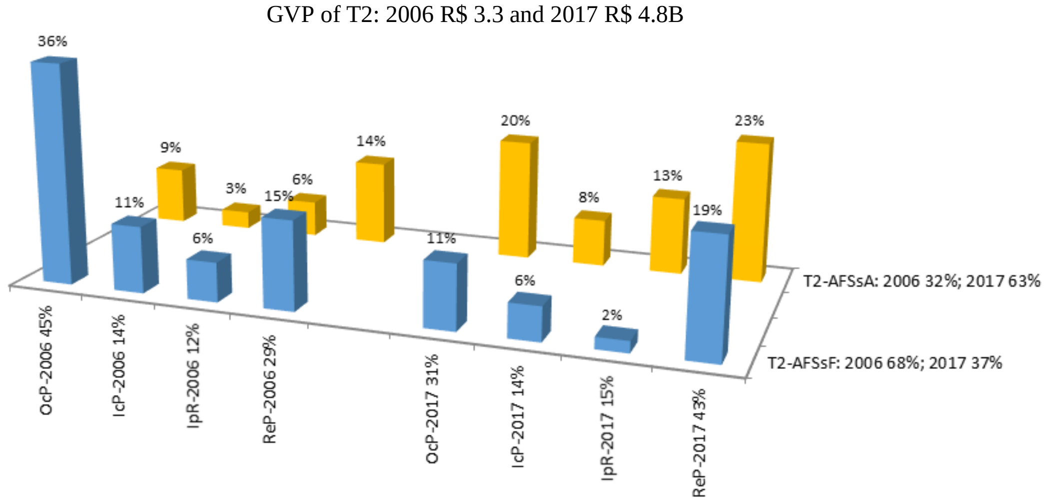
Average of the T2: in 2006 R$ 8.34; in 2017 R$ 8.28



Source: IBGE, AC (2006; 2017) and Costa (2022: *Table3_NorthRegion_T2_KeyVariables.csv*).

Figure 14
The T2 by peasantry and technological variant (% of the GVP of T2)

GVP of T2: 2006 R$ 3.3 and 2017 R$ 4.8B



Source: IBGE, AC (2006; 2017) and Costa (2022: *Table3_NorthRegion_T2_KeyVariables.csv*).

4.2 The determinants of variations in NI_{FW}^{*}

Equation (4) specifies that alterations in the average net earnings of the family laborer are contingent upon both the internal production parameters encapsulated by their physical productivity and the external factors pertaining to trade terms. As follows:

$$\Delta NI_{FW}^{*} = \Delta r + \Delta(p_v - p_c) \quad (5)$$

Consequently, if $r = \frac{Q}{W}$, where Q represents the total quantity produced and W represents the total family workers, then:

$$\Delta r = \Delta Q - \Delta W \quad (6)$$

The variation of Q is found as a variation of the "real product" (RP): for each year, the vector of quantities produced multiplied by a vector of fixed prices:

$$RP_i = \sum_{i=1}^{3} \sum_{j=1}^{n} q_{i,j}\, p_{2,j} \quad (7)$$

Here i represents the year, j denotes the product, $q_{i,j}$ signifies the quantity of the product j in year i, and $p_{2,j}$ the price of the product *j* in the fixed year 2. The variation of RP is solely accounted for by the variation in Q, represented as an aggregate of q_j, in each year, as the set of prices p_2 remains constant across the years.

Therefore, if changes ΔQ and ΔW are known, then Δr in equation (6) can be determined. Similarly, if ΔNI_{FW}^{*} is available, it follows from equation (5) that Δ(pv-pc)=ΔNI_{FW}^{*}-Δr (procedures and results in Costa, 2022: *Table3_NorthRegion_T2_RealProduct.csv* and *Table3_NorthRegion_T2_KeyVariables.csv*). Consequently, it becomes feasible to examine the determinants of the progression of NI_{FW}^{*}, and to validate the evolution of t reproductive efficiency in T2.

The solid growth of the NI_{FW}^{*} in T2 between 1995-2006, at 6.9% p.a., was explained by the corresponding growth of *r*, at 7% (ΔQ=3.8% and ΔW=-3.2%) (Figure 15). This was with a decreasing family work force and stable trade terms (Costa, 2022: *Table3_NorthRegion_T2_KeyVariables.csv*).

Between 2006 and 2017, the NI_{FW}^{*} achieved in 2006 remained in a context of decreasing productivity at -0.9% p.a. (ΔQ=0.7%; ΔW=1.6%), and the equivalent improvement in exchange ratios within the scope of T2. However, there were differences between the technological variants and their operations in the territories.

1. A drop in the AFSs-F NI_{FW}^{*}, at -1.2% p.a., resulted from a drop in the physical productivity at -2.1% p.a., partially offset by an improvement in trade terms to 0.9% p.a. The NI_{FW}^{*} of AFSs-A, higher than AFSs-F, dropped during the period at -1.8% p.a., resulting from r and p_v/p_c also declining at -0.9% p.a. (Figure 15)

2. The greatest decreases in *r* occurred amongst the caboclo peasants, more accentuated in AFSs-F (the OcP at -6.1% p.a., the IcP at -3.2% p.a.), but also in AFSs-A (the OcP at -1, 8% p.a.; the IcP at -2.1% p.a.). Amongst these peasants, there were, specifically, expressive improvements in trade terms (in AFSs-F, in the OcP at 3% and the IcP at 2.6% p.a.; in AFSs-A, in OcP at 1.6% p.a.) which, however, did not prevent generalized reductions in the NI_{FW}^{*}.

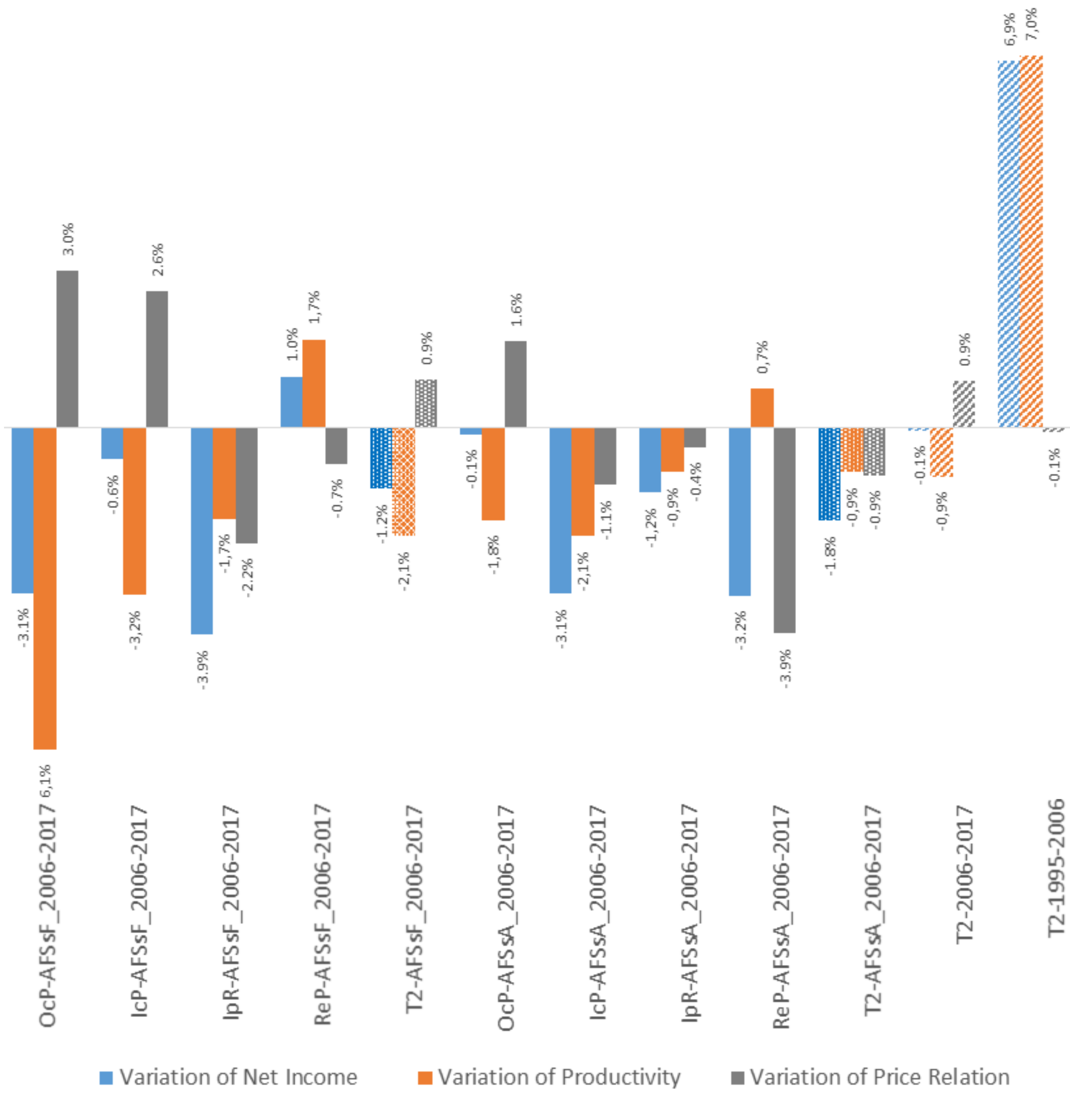
3. A drop in *r* was also seen in the IpR, combined with a reduction in the p_v/p_c and a severe reduction in the NI_{FW}^{*}.

4. An increasing *r* was only observed in the ReP, both in AFSs-F (at 1.7%) and in AFSs-A (at 0.7% pa); in the latter, however, a sharp drop in the price ratio led to a sharp reduction in the NI_{FW}^{*}.

A general statement is that reproductive efficiency along with NI_{FW}^{*} were in decline in T2 with one exception: the ReP in AFSs-F. This trend, based on a generalized drop in productivity, for both AFSs-F and AFSs-A, eventually offset by better trade terms, would become stronger, if the greater reduction in the number of average workers (W), discussed above, which reduces RC_{FC} in (3), is not balanced by the number of consumers and, even more, if the consumption paramet (c) become greater – both probable facts, but that cannot be addressed in this study.

Figure 15

Production by average establishment of T2 technological variants at the ReP in 2006 and 2017



Source: IBGE, AC (2006; 2017) and Costa (2022: *Table3_NorthRegion_T2_KeyVariables.csv*).

Conclusion

This paper has presented the foundations and dynamics of T2, with reference to the different peasantries, which together with their respective territories, have played a leading role. Changes were analyzed in the aggregate production structures in the territories resulting from production restructuring within the establishments. On a micro level, the changes were guided by the NI_{FW}^{*}: the NI_{FW}^{*}, of the AFSs-A variant, invariably higher than those of the AFSs-F, which led to systematic displacements of establishments from this to the former that, with 63% of GVP, in 2017 became the most important within T2. The AFSs-A evolved with the agricultural and livestock components. Amongst the first, the "roças de várzea" and "roças de caboclo" were the dominant AFSs with a long tradition in obtaining products, such as acai berry and manioc flour amongst the OcP and IcP peasants. The more laboratory-based AFSs, the result of innovations emerging from technical agricultural culture, were organized by the IpR and ReP around commodities such as black pepper, cocoa and planted acai berry. Cattle ranching, in turn, presented traditional components, adjusted for long-term practice by the OcP, with recent increasingly important components, in the IcP, IpR and ReP.

The growth of AFSs-A, with these elements, seems to have been fundamental in the NI_{FW}^{*}, doubling between 1995 and 2006, helped by physical productivity that grew at 7% p.a. Nevertheless, its advance occurred between 2006 and 2017 with decreasing physical productivity and constant profitability – dependent, therefore, on a favorable price ratio. This, however, may deteriorate swiftly, depending on the success of other trajectories, such as the wage-based T5, which rapidly expanded homogeneous irrigated acai berry plantations, for example.

The growth with decreasing *r* between 2006 and 2017 indicated that the set of changes conducted in the previous phase – the intensification and planting of acai berry, the introduction of permanent exotic crops and the expansion of cattle ranching – exhausted the potential for gains, and difficulties were manifested in attempting to overcome these limits. Recent research by ecologists and botanists has shown that Climate change is interfering negatively in the production of açaí in hot years (Tregidgo et al., 2020), whose productivity in general has been affected by the effect of the erosion of diversity resulting from the greater intensification of the *açaizais* management (Freitas et al., 2015; Campbell et al., 2017).

On the other hand, the verified improvement in trade terms in the OcP and IcP indicates a reduction in asymmetries in external relations that allowed the producer to capture part of the gains obtained in industrial processing and in merchandising his products. These are strategic policy questions, when T2 is seen as the basis for sustainable development: how to strengthen it while maintaining or increasing productivity or/and valuing its production and ensuring internalization of results? Little has been done in any of these alternatives. In fact, T2 has generally been the lowest policy priority for delivering capital and knowledge. Furthermore, when considering T2, this seems to have occurred by "forcing" elements from other trajectories (or livestock farming, or single permanent culture), such as an exogenous and competing agency. To maintain an upward path, T2 requires the contrary: an institutional environment adjusted to its singularities delivering the influx of capacities that it requires – to handle less with specialized activities and more with complex, diverse productive system; to promote the specification (instead of commoditization) of products; to improve the organization of commercialization.

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