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Structural diversity and change in rural Amazonia: a comparative assessment of the technological trajectories based on agricultural censuses (1995, 2006 and 2017)

Diversidade e mudança estrutural da economia agrária da Amazônia: uma avaliação comparativa das trajetórias tecnológicas com base nos censos agropecuários de 1995, 2006 e 2017

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Abstract

By applying methodological notions developed by Costa (2009), the present article sets out to define rural techno-productive trajectories in the Amazon, and compares their evolution with data from the agricultural censuses of 1995, 2006 and 2017. By highlighting the growth of each trajectory, the article discusses their fundamentals, set within the context of technological variants that have critically depended either on land or on labour, and were relatively intense, either in mechanical-chemical components or in the use of forest resources or permanent plantations. The results have underlined the significance that trajectories based on temporary crops and beef cattle have assumed within the region, as well as the risks and structural changes that this has involved. Results have also demonstrated the contrast represented by trajectories based on agroforestry systems and permanent crops.

Keywords

Brazilian Amazonia, Agrarian Development, Rural Technological Trajectories.

JEL Codes O13, O17, O33, O44, Q15.

Resumo

Utilizando noções metodológicas desenvolvidas por Costa (2009), o presente artigo delimita trajetórias tecnoprodutivas rurais na Amazônia e compara sua evolução com dados dos censos agrícolas de 1995, 2006 e 2017. Destacando o crescimento de cada uma dessas trajetórias, discute seus fundamentos no contexto de variantes tecnológicas que dependiam criticamente da terra ou do trabalho, eram mais ou menos intensas em componentes mecânico-químicos ou no uso de recursos florestais ou plantações permanentes. Os resultados destacam o peso que as trajetórias com base em culturas temporárias e bovinos de corte assumiram na região, bem como os riscos e as mudanças estruturais que isso envolve. Os resultados também demonstram o contraponto representado pelas trajetórias baseadas em sistemas agroflorestais e culturas permanentes.

Palavras-chave

Amazônia brasileira, Desenvolvimento Agrário, Trajetórias Tecnológicas Rurais.

Códigos JEL *O13, O17, O33, O44, Q15.*

1 **Introduction**

The rural reality of the Amazon is characterized by a deep-seated structural diversity. Historically, long-standing large-scale farmers and peasants (Costa, 2019; Nugent, 1993) together with the recently-arrived large-scale farmers and peasants (Costa, 2012a; Becker, 2007 and 2001; Schmink, 1982, Martins, 1980; Velho, 1976) have interacted with one another and with the highly diverse, complex nature of the region, mediated by different institutionalities and alternative technical resources (Costa, Fernandes, 2016; Hecht, 1985), thereby shaping the multifaceted, tense reality that now exists. Such differences have not remained neutral with regard to vital issues involved in the development of both the region and the country, and which have had critical implications in relation to land uses, the associated environmental impacts and in reducing poverty (IPCC, 2019; Costa, 2016). They are also of relevance with regard to the desire of industrial and financial capital to expand the country's internal and external market across the region (Costa, 2005).

Aiming to describe this multidimensional reality, and detecting trends in its evolution, Costa (2009, 2012b:130-182 and 2013), inspired by the works of Dosi (1982; 1988) and Arthur (1994) and, considering features from the Brazilian Agricultural Census, has suggested a methodology to chart technological trajectories – productive trajectories and their technological variants. Thus, the concept has been applied as a unit of analysis on a mesosystemic level, which lies somewhere between the micro dimension of the rural establishments and the regional agrarian economy as a whole.

Initially, the methodology distinguishes between the agents, and the rationalities behind their decision-making, and the structural context of peasant and capitalist modes of production, and seeks to capture the convergence of the production systems in the technological trajectories guided by major technological paradigms. Production systems represent the different manners by which the agents, from within the constraints of the structures specific to their modes of production, combine both the tangible and intangible, and the natural and institutional means available to them. The agrarian economy thus becomes a unit of the diversity of the technological trajectories, therefore, a development of the former, a movement synthesis of the evolution of the latter.

The aims of the article are: a) to approach Costa's methodology and its theoretical foundations; b) to improve it, so that it better encapsulates the technical variants; c) to apply it to the results of the 2006 and 2017 Brazilian agricultural censuses, and then d) to compare the results for the different modes of production and their technological trajectories in the Amazon, represented by the nine states in the Northern Region of Brazil, with those from the 1995 Agricultural Census, reported in the aforementioned study. Within the short space of this text, I set out to explain the major structural changes substantiated in the composition of the regional agrarian production, between the modes of production and their trajectories. There is also the intention to develop a preliminary synthetic discussion on some of the fundamentals of these changes, together with the technological variants on which they have been based, and the corresponding trends encountered in the use of land and labour. In addition to this introduction, the article is made up of three sections. Section 2 presents the theoretical notions that establish the technological trajectory as a unit of analysis, and the methodological steps that represent them (the developments of which are described in detail in Appendices A and B), using data from the Brazilian agricultural censuses. Section 3 presents the aggregate results of the agrarian economy in the Northern Region of Brazil, and Section 4 discusses the results for the different modes of production and their trajectories and the technological variants. Lastly, the conclusions are presented.

2 **Trajectories and technical variants as analytical units of the diversity of the agrarian economy**

Dosi defined a technological paradigm "... as a 'model' or 'pattern' of solutions of selected technological problems based on selected principles derived from natural sciences and on selected material technologies. (...) At the same time, technological paradigms define also some idea of progress" (Dosi, 1982, pp. 22-23). From this perspective, a technological paradigm constitutes: a) a "perspective" for defining relevant problems in the light of a notion of progress, and b) a set of procedures – heuristics – for solving such problems, of which the state of knowledge on nature is a decisive part. On the other hand, a paradigm offers a possibility from amongst other possibilities within the organization of social reproduction, hence, its material (historical) existence, c), results from selection mechanisms c.1), associated with the economic dimension and c.2), with other dimensions of life in society, particularly culture, politics, and science (Dosi, 1988).

The immediate presence of nature as a productive force accounts for the main difference between agriculture and industry under capitalism. Industrialist (industrial-capitalist) rationale seeks to reduce this presence and control its significance – as it does with regard to human labour. Such an effort has been responsible for organising the paradigm of agricultural modernization, in terms of its industrialization. Goodman, Sorj and Wilkinson (1987) demonstrated two major trajectories of rural industrialization: one represented by a set of technological solutions that succeed as an industrial effort to appropriate roles played by nature, and another by a set of solutions that seek to replace products from living nature by inorganic products obtained in the laboratory (*i.e.*, industrially). Hayami and Ruttan (1971) observed that mechanics and chemistry play prominent roles within these processes, the first being the main foundation of solutions where there is an abundance of land, and the second, where this factor is limited.

Thus, a technological paradigm has asserted itself on a global level through sets of solutions selected for efficiently controlling nature, so that it corresponds to industrial and capitalist needs. Such industrialist solutions succeed one another, composing technological trajectories marked by the intensive use of mechanics and chemistry and by the presupposed or resulting formation of homogeneous botanical and biological systems dependent on fossil energy sources (Dunlup; Beus, 1990). Moreover, on a global level, alternative forms of rural production have also been developed in trajectories guided by other principles, either agroecological or agroforestry. This has thereby configured a paradigm that guides technological solutions in a perspective that is harmonious with the original nature, of managing the diversity of botanical systems and their autonomy in relation to exogenous sources of energy and nutrients (Collicott, 1990; Drengson, 1985; Hecht, 2010).

Technological paradigms materialize through technological trajectories. Technological trajectories are the usual patterns of activities which, based on a technological paradigm, solve the productive and reproductive problems that confront the decision-making processes of particular agents in specific contexts in the economic, institutional, and social dimensions (Dosi, 1982; 1988). From another perspective, "a technological trajectory is a cluster of possible technological directions [variants] whose outer boundaries are defined by the nature of the paradigm itself" (Dosi, 1982, p. 24).

The particularities of the economic context are established in the "… economic criteria acting as selectors defining more and more precisely the actual paths followed inside a much bigger set of possibilities" (Dosi, 1982, p. 23). Considering the high level of uncertainty surrounding the adoption of technologies, the institutional environment assumes particular relevance within the configuration of the technological trajectories, from the economic interest of organizations, through the respective histories and accumulations of expertise, to the strictu sensu institutional variables, such as public agencies and geopolitical interests (Dosi, 1982, pp. 24-25; Dosi, 1988).

The methodology proposed by Costa (2009; 2012b) for identifying technological trajectories in the agrarian sector of the Amazon prioritises their economic and institutional "filters". Thus, it begins by assessing the production results of the establishments. The operational maxim is that "products are trajectory phenomena" (Costa, 2009, p. 50), which are constituted and developed as a result of the respective performances in the social division of labour (local, national, or worldwide) in systemically defined contexts – in both structural and territorial terms.

Structurally, the establishments, across the same territory, using similar private criteria, that produce goods correlated by the logic of demand (identical, complementary or substitute products) or supply (production, the basis of which needs to be renewed each year, production on a more or less perennial basis, production that integrates animals and plants, production that integrates forest and agriculture, etc.), share similar technological and market problems and solutions. Therefore, they compete or cooperate in order to obtain resources (access to land, availability of work, sources of loan capital, sources of knowledge, etc.), place their products onto markets, or other forms of common economic organization, and converge towards dominant solutions. According to Arthur (1994), technical variants, through their products, are subjected to market and other institutional tests, the results of which are assimilated by companies (peasant and employer agricultural establishments), in a dynamic interaction that leads to convergences and solutions that materialize in the technological trajectories. Thus, underlying technical standards correspond to the patterns of production results so that defining the latter enables the existence of the other to be inferred. Furthermore, these underlying technical patterns are able to safeguard capacities for mutual interference, whereby the development or lack of development in one may stimulate or restrict development in others (Dosi, 1982, p. 24). Hence, by defining the trajectories guided by defining the patterns of production results, the manner in which product groups relate becomes relevant.

Territorially, technological trajectories interact within the context of local agrarian systems, the agrarian dimension of local economies, where institutional and natural specificities operate in the most tangible manner. Agrarian systems throughout the territory are expressions of the materialization of rural technological trajectories in either competitive or cooperative interaction.

Hereafter, the technological trajectories will be outlined in four steps. In the first, in order to arrive at the patterns of production results, the product groups, informed by the agricultural censuses under the categories of "products of temporary crops", "products of permanent crops", etc., have been identified for each mode of production. Multivariate regressions were used with regard to their respective importance in the social division of labour (relative weight in the composition of regional production), the ability to pay the agents involved (net profitability of peasant or employer companies) and investment capacity (the demonstrated ability to contribute to the expanded reproduction of the structures under consideration). In the second step, the interaction patterns between these product groups are verified by factor analysis.

Factor analysis is a multivariate statistical analysis technique that aims to identify the underlying structures in a set of observed variables, enabling two types of results: data summarization and data reduction (Backhaus *et al*., 2000, pp. 252-327). In the summarization processes, the latent variables (the factors) are explained by the variability patterns of the manifest (real) variables and the factor loadings of each variable in relation to the factor. A factor is a construct, a hypothetical entity, an unobserved variable, the reality of which lies only in the fact that it explains the variance of observed variables. The factorial loadings obtained are coefficients that express how much an observed variable is loaded or saturated in a factor. In reduction processes, the factors may be transformed into entirely new variables, which may then be included in subsequent analyses (Hair *et al*., 1998, p. 95).

In the third and decisive step of the methodology, the resulting factor structures – the main components and the factor loadings of each product group in explaining their variance – are compared with the attributes of the different product aggregates indicated in the first analytical step. These are assessed as possible expressions of techno-productive trajectories and submitted pari passu to available (tacit scientific) knowledge, as tests that corroborate historical-structural meaning and locational accuracy, *i.e.*, that explain their position in tangible agrarian systems. In Appendix I, the procedures mentioned thusfar have been applied to data from the Agricultural Censuses of 2006 and 2017, the results of which are presented as the criteria for delimiting the trajectories.

Given that products are phenomena of the essential reality of technologies (Costa, 2009, p. 50), the abovementioned characterization of trajectories based on products put into circulation empirically establishes the context of operation and, therefore, the framework for determining the technological variants that underlie them. Thus, there is the fourth, and additional step (in relation to Costa's proposal, 2009), of the methodology. Methodologically, technological variants are associated with patterns of occurrence in the census data of the technological characteristics of the establishments within the context of their respective trajectories. A further factor analysis is then undertaken with variables that indicate the mechanical, chemical and labour intensity for systems dominated by temporary cultures; the chemical intensity and biological intensity for systems dominated by livestock; and the intensity of native forest, planted forest and permanent crops, for plantations or agroforestry systems. Initially, the results expose the technological standards of each trajectory for each census year (see Appendix B). Following on, the results of the two most recent censuses are then compared. This makes it possible to infer the interaction of these technical standards over time, either as a succession of phases of the same technological variant, or as a succession of patterns as a result of competition between variants, one replacing the other, or even as patterns that converge in the formation of unusual syntheses – new variants and technological trajectories.

3 **The agrarian economy of the Northern Region of Brazil**

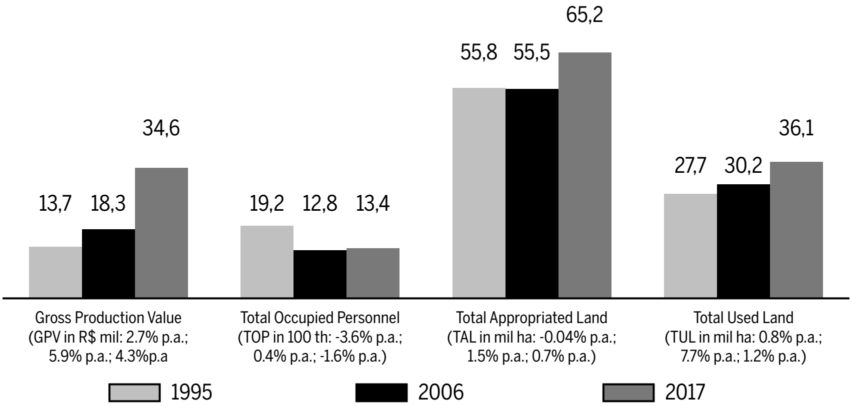
The rural economy of the Northern Region of Brazil has grown at remarkably high rates over the last two decades. Its Gross Production Value (GPV) increased at 4.3% p.a., from R$ 13.7 to R$ 34.6 billion between 1995 and 2017 (all figures have been adjusted to the 2019 Real). There were, however, differences in the growth rate between the periods, the first, rapid (2.7% p.a.); the second, accelerated (5.9% p.a.) (see Figure 1).
This process involved large-scale land grabbing and preparing it for agriculture and livestock: the amount of land in rural establishments increased by 9.4 million hectares – approximately 17% over the stock of 55.8 million hectares declared by agricultural establishments in 1995. During this period, the pace of transforming land with forest into land with agriculture and pasture (TUL) was greater than the pace of the land appropriation process (TAL), 1.2% and 0.7% p.a., respectively, the average proportion of the former within the latter grew from 49.6% in 1995, when it comprised 27.7 million hectares, to 55.4% in 2017, when it totaled 36.1 million hectares.

The number of employed personnel decreased to –1.6% p.a, from almost 2 million occupations in the first census, to approximately 1.3 million occupations in the last. Strictly speaking, there was a significant drop of –3.6% p.a. in the first inter-census period and, in the second, a slight recovery at 0.4% p.a.

These aggregate figures enable us to first characterize rural growth in the Amazon, during the observed periods. For this, Hayami and Ruttan's meta-function will be used. Hayami and Ruttan (1980) proposed a "meta-production function" of agricultural growth that makes the product (Y, equivalent, in Figure 1, to GPV) equal to the monetary productivity of land (MPLd = Y/T, equivalent to GPV/TUL) multiplied by the land-labour ratio (LLR = T/L, equivalent to TUL/TOP) and the number of applied workers (L, equivalent to TOP, in Figure 1). With this simple model, it is possible to differentiate rural growth, first, with regards to the monetary productivity of labour (MPLb = Y/L, equivalent to GPV/TOP), indicating growth with increasing, constant or decreasing yields; and second, by discerning, from the observation of the determinants of the MPLb – the monetary productivity of land (MPLd) and the land-labour ratio (LLR) – the technical variants of this process, whether more or less labour or land intensive, whether more or less less dependent on chemistry, mechanics or botanical ecology.

In the Northern Region, during the periods in question, the growth of the agrarian economy was accompanied by an increase in the MPLb at high, although decreasing, rates, 6.6% and 5.5%, respectively, in the periods 1995-2006 and 2006-2017 – an average of 6.1% p.a. The growth in MPLb, in turn, depended, in almost equal proportions, on the growth of the MPLd, at 3.1% p.a., from R$ 493 in 1995 to R$ 958 in 2017, and the 3.0% increase in LLR, from 14.4 to 27.1 hectares/worker.

Figure 1 **Evolution of critical variables of the agrarian economy in the Northern Region in 1995, 2006 and 2017**



Source: IBGE, Agricultural Censuses 1995, 2006 and 2017.

Notes: The units are in parentheses, followed by the growth rates of the variables in the following sequence: between 1995-2006, 2006-2017 and 1995-2017.

4 **Production modes and technological trajectories**

4.1 **The peasant segment and its trajectories**

The agrarian economy of the Amazon is based on two fundamental modes of production, that of the peasant and the employer (or capitalist). Rural peasant establishments are distinguished from those of employers in that they have decisive parameters within the family, both with regard to the available workforce and to defining consumption needs. The union between the spheres of production and consumption brings a decision-making rationality to this economy guided by the evaluations of reproductive efficiency: the degree of average affluence with which people live and the stability of this condition along a temporal horizon defined by the evolution of the family group – by the birth and growth of children and the aging of parents (Costa, 1995; 2019; based on Chayanov, 1923 and Sahlins, 1972). The most notable result of this, historically demonstrated, is the high capacity to adapt to circumstances – a resilience almost always based on the diversity and flexibility of using the available capacities, along with a circumstantial malleability with regard to the corresponding consumption patterns (Costa, 2019, pp. 126-29; pp. 142-47; Costa, 2012c; Costa, 1995).

Employer establishments on the other hand, based on wage labour, are predominantly oriented towards the return of capital-money invested in the production process. These, therefore, decide on the basis of what Keynes called, the marginal productivity of capital: an intertemporal evaluation between the forms in force and their future possibilities, and the alternative forms of capital appreciation, whereby the ultimate reference is the average gain of financial capital (Keynes,1970).

According to Costa (2009), in 1995, there were three peasant technological trajectories. The first, which he named "Peasant Trajetory.T1" (Costa, 2012b, pp. 159-60), with 171,292 establishments, was driven by relatively specialized agricultural production, of both temporary and permanent crops. At the time, T1 expressed a trend, detected from the eighties onwards, towards the existence, across the entire region, of single plantations of permanent crops, which in certain areas (particularly in the state of Rondônia and in the Southeast of the state of Pará), included a few dairy cattle, similar to what has been observed in the peasant regions of origin, mainly in the southeast of the country, with coffee and dairy products, and parts of the northeast, with dairy products and fruit. Temporary cultures, as previously mentioned, often made up the systems of these establishments, although with a secondary role in their dynamics. In 1995, with 171 thousand establishments, T1 produced goods worth R$ 4.0 billion – 45% of the GPV of peasant production, and 29% of the total production during the same year.

The second, "Peasant Trajectory.T2", was undoubtedly highlighted by the importance of extractivism (non-timber) in the production systems, along with a very wide variety of compositions amongst the different groups of products. This was clearly a trajectory based on agroforestry systems (AFSs). Peasant Trajectory.T2 was made up of 130,593 establishments with a combined GPV of R$ 2.4 billion – representing 27% of the total peasant production and 18% of the total production in 1995.

Lastly, "Peasant Trajectory.T3", with 109,405 establishments producing R$ 2.5 billion, approximately as significant as the previous, was defined by the weight of beef cattle – its dynamic being led by relative specialization in this activity.

Three associated movements were observed from these trajectories in the following two censuses, thereby leading to important structural changes in the context of peasant production across the region. As follows:

4.1.1 *A reduction of T1, accompanied by its specialization in temporary agriculture*

a) During the period 1995-2017, production decreased to R$ 2.4 billion in 2006, recovering partially in 2017, when the GPV reached R$ 3.2 billion – an average reduction to –1.1% p.a. (Figure 2). The specialization is demonstrated by the fact that in its systems, temporary cultures (cassava, pineapple, corn, rice) began to represent 81% of the GPV in 2006 and 60% in 2017, whereas in 1995, they had represented 34% (Figure 3).

b) The reduction in T1 was accompanied by an increase in its MPLb from R$ 5.5 to R$ 12.8 thousand per worker/year between 1995 and 2006, with a decrease, in the following period, to R$ 10.4 thousand (to year 1995, Costa, 2012c, op.cit. p.153; to years 2006 and 2017 Table B2; variation 2006-2017 Figure 5). These variations, by hypothesis, may, at first, have been the result of composition effects, insofar as less profitable activities, reducing reproductive efficiency, were either contained or eliminated; or they began to be developed by new technological variants in the context of the T1 trajectory itself. In this case, put to the test in the following period, these alternatives would have shown to be limited.

c) The 2006 Census indicated the use of chemical inputs in T1's production systems, and mechanical investments were also announced. Clear standards, however, were only offered in the 2017 Census, in which two variants of the mechanical-chemical technological paradigm were revealed, whereby one variant combined high mechanical (and chemical) intensity with low labour intensity (LI) and other combined high chemical intensity with high labour intensity (see Table B1). The two variants collaborated positively in forming the GPV of T1 (Figure 4). The first with decreasing gains and the second with increasing gains from labour (MPLb) (see Figures 4 and 5).

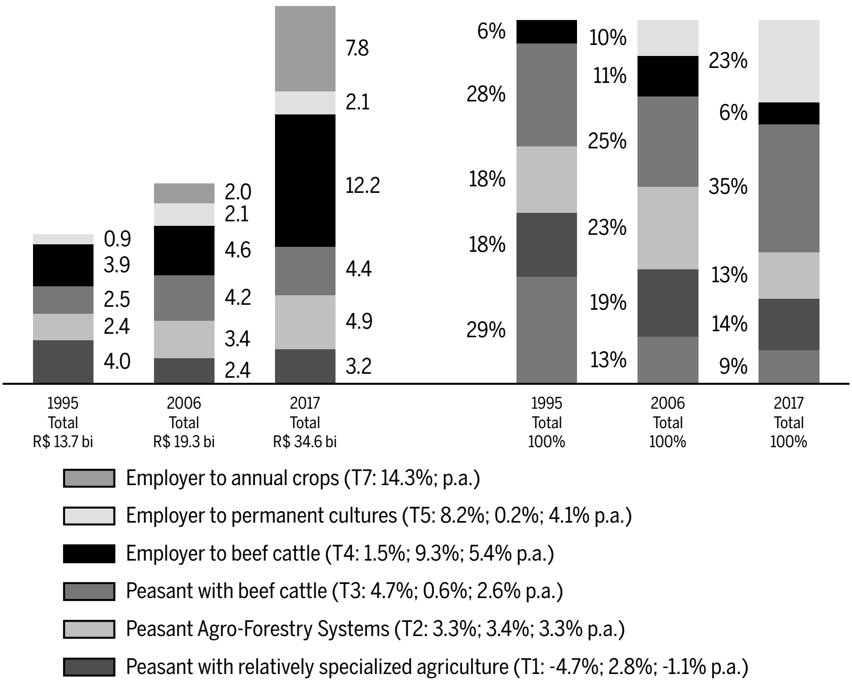
4.1.2 *Increasing the absorption of permanent cultures by T2, originally present in T1*

a) The GPV of T2 grew to R$ 3.4 billion in 2006 and to R$ 4.9 in 2017 – at an average of 3.5% p.a. from 1995 to 2017 – with permanent crops (açaí, black pepper, banana, cocoa) representing 16%, 24% and 19% respectively. Here, the adoption of permanent crops in peasant systems followed different principles of specialization found in T1 in 1995, with a prevailing diversification and synergistic composition between species – the principles of agroforestry systems (Costa, 2020).

b) The growth of T2 was achieved by increasing labour productivity during the first period, from R$ 4,800 in 1995 (Costa, 2012b, p. 153) to R$ 10,000 in 2006, and again to R$ 11,500 in 2017 (Table B2).

c) T2 grew, based on two technological variants of agroforestry systems, the materialization of an alternative paradigm to mechanical-chemical. One began by managing the use and growth of the primary forest and from this, constituted increasingly managed systems, resulting from a composition of permanent crops and silviculture, temporary agriculture and aquaculture. The other began from (almost) exclusively agricultural uses, and incorporated forest elements that reconstituted the biome functions in the AFSs that mimic its characteristics (Costa, 2012b, p. 160). While the second variant grew in absolute terms, the first decreased, between 2006 and 2017, correlated with the respective monetary productivity of labour.

Figure 2 **The GPV of technological trajectories in the agrarian economy of the Northern Region in 1995, 2006 and 2017**



Source: IBGE, Agricutural Censuses 1995, 2006 and 2017.

Notes: Values in R$ billion at 2019 prices and relative structure in% of the total; in the legends, the percentages refer to the annual growth during the periods 1995 to 2006, 2006 to 2017 and 1995 to 2017, respectively.

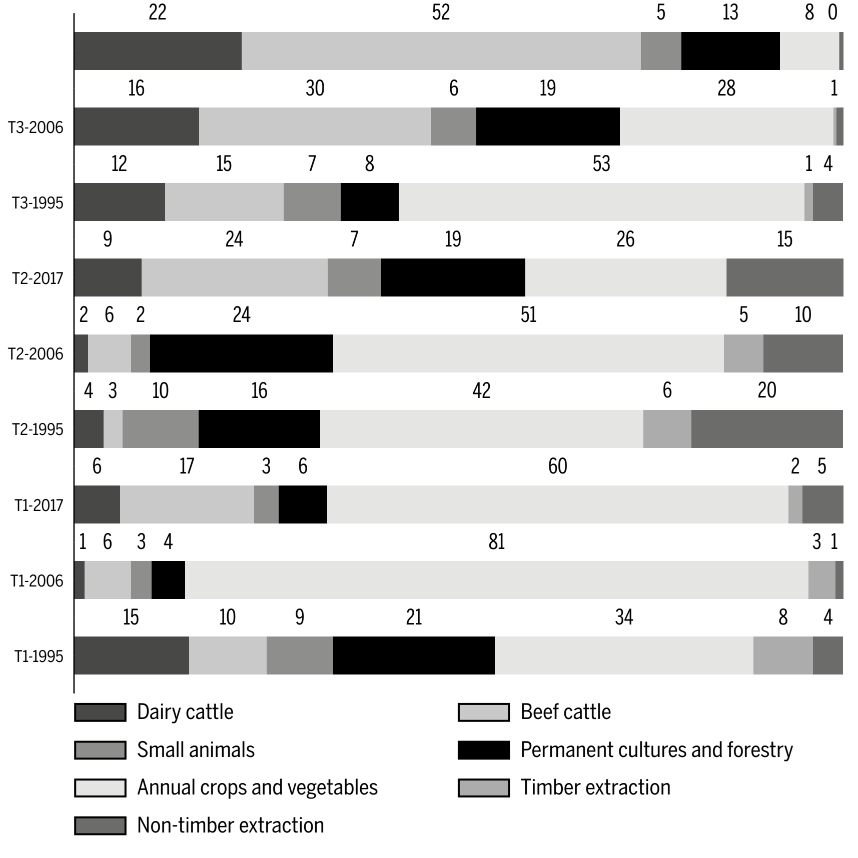
4.1.3 *T3 grew, specializing more and more in livestock. Mainly beef, but also dairy herds*

a) The GPV of T3 reached R$ 4.2 billion in 2006, and R$ 4.4 billion in 2017 – increasing during the first period 4.7%, the last period to 0.6% p.a. and, over the whole period analyzed, to 2.6% p.a.

b) In 1995, 15% of T3's GPV came from beef cattle, in 2006, 30%, and in 2017, no less than 52%. The relative importance of dairy farming, originally significantly present in T1, now grew sharply in T3 from 12% in the first census, to 22% in the last. In T1 it dropped by 6%.

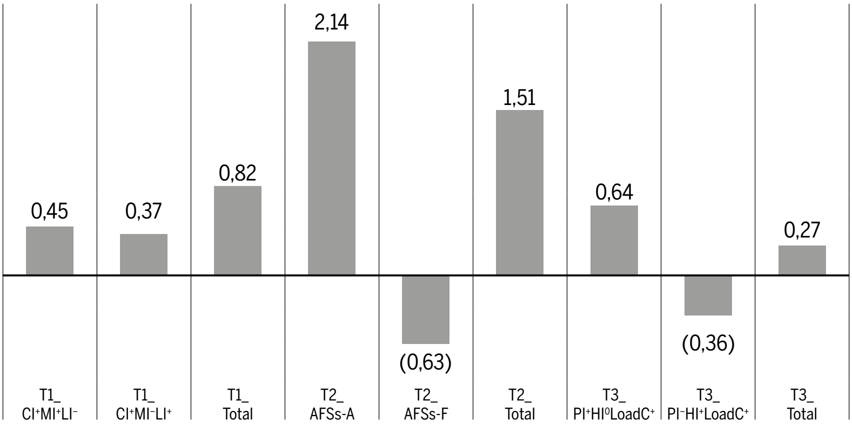
c) T3 presented two technological variants. One was based more on improving herds than on pastures, thereby implying a relatively more extensive use of land (the MPLd, the lowest amongst peasants, remain the same, and the LLR, the highest, more than doubled during the period, see Table B2). The other evolved bringing about improvements in the herd and pastures, resulting in more intensive land use. Both variants developed with increasing MPLb: the first more than tripled, from R$ 6.4 thousand per worker to R$ 21.8 thousand; the second doubled, from R$ 9.6 thousand to R$ 19.2 per worker.

Figure 3 **Composition of the production of the peasant technological trajectories, 1995, 2006 and 2017, as % of GPV**



Source: IBGE, Agricultural Censuses 1995, 2006 and 20017.

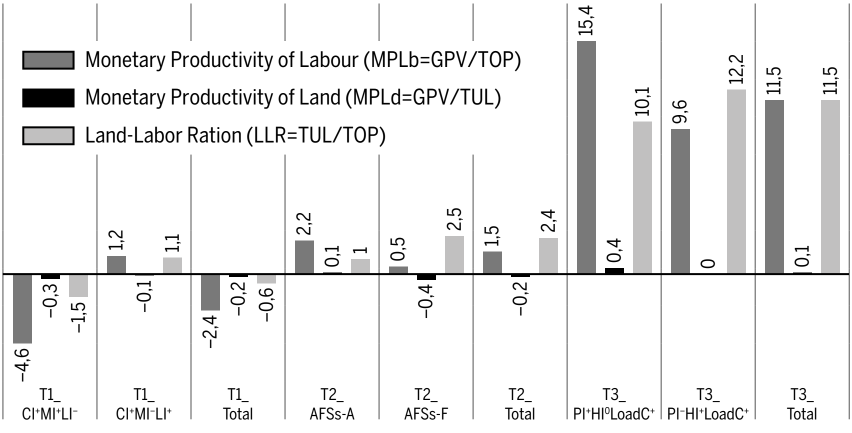
Figure 4 **Variation in GPV associated with peasant trajectories and their technological variants between 2006 and 2017, in R$ Billion at 2019 prices**



Source: Table B2.

Notes: 1) CI = Chemical Intensity; 2) MI = Mechanical Intensity; 3) LI = Labour Intensity; 4) Total: Total of the trajectory; 5) PI = Pasture Improvement; 6) HI = Herd improvement; 7) AFSs-F = AFSs with the presence of forest management; 8) AFSs-A = Artificially developed AFSs; LoadC = Load Capacity of Pasture; 9) "+" after the atribute = Attribute clearly verified; 10) If "−" = Attribute clearly absent; 11) If is "0", an uncertain attribute. 12) See descriptions of the different patterns in the notes in Table B1.

Figure 5 **Variation in the MPLb, MPLd and LLR of the peasant trajectories and their technological variants, between 2006 and 2017, in R$ Thousand per year**



Source: Table B2.

Notes: 1) CI = Chemical Intensity; 2) MI = Mechanical Intensity; 3) LI = Labour Intensity; 4) Total: Total of the trajectory; 5) PI = Pasture Improvement; 6) HI = Herd improvement; 7) AFSs-F = AFSs with the presence of forest management; 8) AFSs-A = Artificially developed AFSs; LoadC = Load Capacity of Pasture; 9) "+" after the atribute = Attribute clearly verified; 10) If "−" = attribute clearly absent; 11) If is "0", an uncertain attribute. 12) See descriptions of the different patterns in the notes in Table B1.

4.2 **The employer segment and their trajectories**

There were three technological trajectories, which in 1995, were the basis for employer production in the Amazon. With a GPV of R$ 3.9 billion, the 27,831 establishments of Employer.T4 were oriented primarily towards beef cattle, to which they applied 18.4 million of the 33.3 million hectares that they controlled.

A second trajectory, Employer.T5, was characterized by the importance of permanent crops in the form of homogeneous plantations. In 1995, there were 4,444 establishments with 29.2 thousand equivalent workers on 755 thousand hectares of a total collection of 2.1 million. A third employer trajectory was also considered in silviculture, with only 3 large establishments that occupied 2,400 people on an area of 1.2 million hectares, of which 137.4 were planted with homogeneous forests (Costa, 2012b, p. 153). In the analysis that follows, for this initial year, the results have been composed for trajectories T5 and T6, by Costa (2009 and 2012c), following the evolution of this aggregate in the following censuses.

During the total period being addressed, there were four essential movements in the employer segment of the agrarian economy in the Amazon:

4.2.1 *The cooling down, or the T4 crisis, with increased specialization and a relative loss of position for T5 and T7 between 1995 and 2006*

a) The GPV of T4 grew during these years at just 1.5% p.a., from R$ 3.9 to R$ 4.6 billion, while T5 grew at 8.2% p.a., from R$ 0.9 to R$ 2 billion. Meanwhile, a new trajectory for grain production emerged, Employer.T7, which, from a practically zero production in 1995, achieved a GPV of R$ 2.0 billion. The relative weight of T4 fell correspondingly, from 82% in 1995 to 53% of employer production, and from 28% to 25% of the total production in the region in 2006 (Figure 2).

b) The specialization of T4 grew throughout the process, with beef cattle farming jumping from 59% to 79% (Figure 6); logging, as in the previous census, remained the second most important item in the trajectory, now with 9%, indicating the structural character that the relationship between these two activities had assumed during the period (Costa, 2012b:153-4).

c) The MPLb and MPLd in T4 were significantly lower than in T5 in 1995, R$ 18.5 and R$ 24.2 thousand per year, respectively, with regard to work; R$ 0.2 to R$ 0.9 thousand with regard to land, according to Costa (2012b, p. 153), a condition which was maintained, despite a reduction in the gap, in 2006, R$ 25.7 and R$ 27.3 thousand per year, with regard to work, R$ 0.3 to R$ 0.4 thousand with regard to land, (see Table B2).

d) In 2006, T7 demonstrated an even higher productivity in relation to both T4 and T5. These differences justified, in pecuniary terms, the transfer of resources from T4 to T5 and T7, and the precedence of the latter over the previous in this phase (issues analyzed in Costa and Fernandes 2016).

4.2.2 *The resumption of an accelerated growth in T4 between 2006 and 2017*

a) T4 grew between 2006 and 2017 at a rate of 9.3% p.a., from R$ 4.6 to R$ 12.2 billion. Accompanying the process, the MPLb and MPLd almost doubled, along with a relative stabilization of the land-labour ratio, confirming the extensive character in lands of the abovementioned growth.

b) In the 2017 Census, two technological variants of T4 became apparent. One was based on the joint improvement of pastures and herds, and the other, presented a low intensity of these same items. The first demonstrated only a slight increase in labour productivity between 2006 and 2017, from R$ 25.7 thousand to R$ 27.5 thousand, as a result of the increase in land productivity from R$ 0.3 to R$ 0.5 thousand, and a significant reduction in LLR from 80.4 to 57.9 ha/worker; the second, in turn, almost tripled labour productivity, from R$ 25.7 to wR$ 67.1 thousand, due to the increase in land productivity from R$ 0.3 to R$ 0.7 thousand, and, also, by the strong growth of LLR from 74.9 to 89.7 ha per worker. In 2017, the relative share of this last extensive variant on land was 75% of the GPV of the trajectory, and its growth depended decisively on it (see Figure 9 and 10).

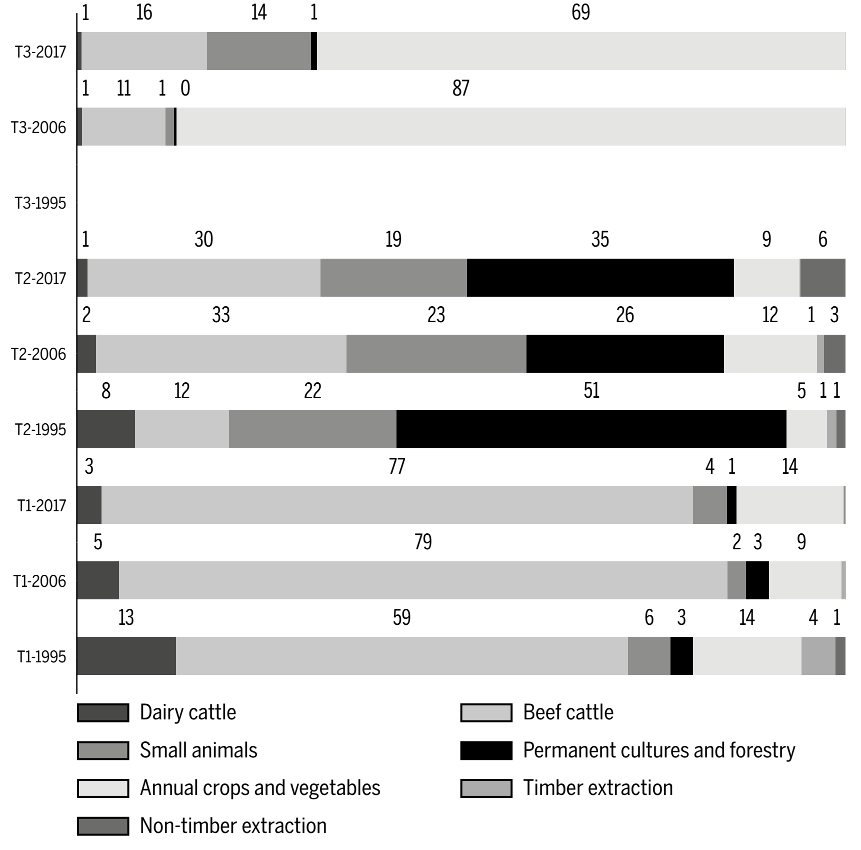
4.2.3 *Accelerated T7 expansion*

a) Between 2006 and 2017, T7 grew explosively from R$ 2 to R$ 7.8 billion (thus, to 13.4% p.a.) producing soy, rice, corn and sugar cane.
b) The growth of T7 was achieved through extremely high labour productivity (approximately five times that of T4 and T5), but then decreased, falling from R$ 132 thousand per worker year to R$ 111.5 thousand. The MPLd, in turn, also high when employer standards are considered (three times that of T4, and twice that of T5), grew from R$ 0.91 to R$ 1.53 thousand/ha. LLR, dropping from 144.4 to 76.2 hectares/worker. However, it remained the highest amongst all employer establishments.
c) In 2017, T7, as with T1 farmer, demonstrated two technological variants of the mechanical-chemical paradigm. The first was based on mechanical (and chemical) intensity and labour economy and the other was based on chemistry and labour intensity. Both variants contributed positively to the growth of T7's GPV, although with decreasing labour productivity; this was combined with stagnant land productivity in the case of the first variant.

4.2.4 *The limitation of T5*

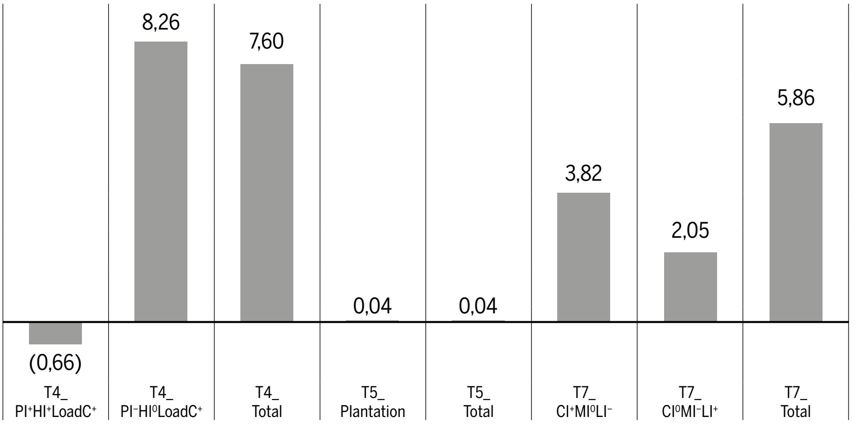
a) T5, which had grown significantly during the previous period, stagnated between 2006 and 2017 at a GPV of R$ 2.1 billion.
b) Despite the growth of the MPLb and MPLd, from R$ 27.3 to R$ 31.5 per worker and R$ 0.41 to R$ 1.3 thousand/ha, respectively, the trajectory did not manage to keep pace with T4 and T7 in the universe of employer production.

Figure 6 **Composition of production in the technological trajectories of the employer segment of the agrarian economy of the Amazon, 1995, 2006 and 2017, % of the GPV**



Source: IBGE, Agricultural Census 2006 and 2017. Costa, 2009.

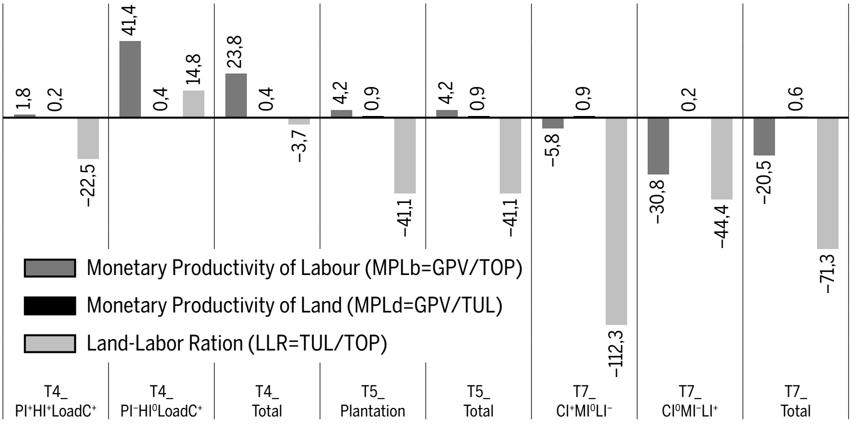
Figure 7 **Variation in GPV associated with trajectories and their technological variants, 1995, 2006 and 2017, in R$ billion at 2019 prices**



Source: Table B2.

Notes: 1) CI = Chemical Intensity; 2) MI = Mechanical Intensity; 3) LI = Labour Intensity; 4) Total: Total of the trajectory; 5) PI = Pasture Improvement; 6) HI = Herd improvement; 7) AFSs-F = AFSs with the presence of forest management; 8) AFSs-A = Artificially developed AFSs; LoadC = Load Capacity of Pasture; 9) "+" after the atribute = Attribute clearly verified; 10) If "−" = Attribute clearly absent; 11) If is "0", an uncertain attribute. 12) See descriptions of the different patterns in the notes in Table B1.

Figure 8 **Variation in the MPLb, MPLd and LLR of the trajectories and their technological variants, 1995, 2006 and 2017, in R$ Thousand per year**



Source: Table B2.

Notes: 1) CI = Chemical Intensity; 2) MI = Mechanical Intensity; 3) LI = Labour Intensity; 4) Total: Total of the trajectory; 5) PI = Pasture Improvement; 6) HI = Herd improvement; 7) AFSs-F = AFSs with the presence of forest management; 8) AFSs-A = Artificially developed AFSs; LoadC = Load Capacity of Pasture; 9) "+" after the atribute = Attribute clearly verified; 10) If "−" = Attribute clearly absent; 11) If is "0", an uncertain attribute. 12) See descriptions of the different patterns in the notes in Table B1.

5 **Conclusion**

The agrarian economy of the Northern Region of Brazil has grown at a high rate of 4.3% p.a. for almost a quarter of a century. During the eleven years that preceded the most recent agricultural census, this growth accelerated, and average rates of 5.9% p.a. were observed. The production modes and technological trajectories that organized the rural areas of the region have provided a distinctive participation in this dynamic.

Taken as a whole, the peasant trajectories grew by 1.6% p.a. over the entire period. Employers, on the other hand, grew at a significantly faster rate, 7.1% p.a. As a result, the composition of the agrarian economy in the Northern Region of Brazil has reversed: the weight of the peasant segment, which in 1995 was 65% and, in 2006, 55% of the GPV, decreased in 2017 to 36% and the employer segment reached 64% in the last year.

The performance of the employers has been due to the speed with which the T4 and T7 trajectories evolved during the last period, at 9.3% and 14.3% p.a., respectively. Considering the technological characteristics of these trajectories, which, despite having reduced their land-labour ratios, still arrived in 2017 with very high values of 75.6 and 73.1 ha/worker (more than three times that of T3, more than eight times that of T2 and more than 11 times that of T1, with regard to the peasant trajectories; three times that of employer T5), this performance, between 2006 and 2017, required the productive incorporation of 4.5 million hectares by T4 and 3.0 million hectares by T7. Hence a total of 7.5 million hectares. These would be the additional deforested areas demanded by these two trajectories during the period – the environmental counterpart of their economic performance.

The T5 employer trajectory, an alternative employer route, with less environmental impact, which had seemed promising between 1995 and 2006, thereafter stagnated, and shifted land resources to other trajectories. The reasons for this reluctance should be further investigated. In this regard, it should be borne in mind that the plantation systems that have been the basis for the trajectory have faced problems in the Amazon. Homogeneous plantations across vast extensions in the region constitute botanical systems of low resilience, which are vulnerable to the countless often unknown pathogens that attack them.

Two peasant trajectories presented systematic growth throughout the period: T2 and T3, at 3.3% and 2.6%, respectively, per year. The remarkable growth of T2 represents the affirmation of one aspect of rural production that, under the aegis of peasant rationality, interacting with ancestral and labouratory knowledge, distanced itself from the mechanical-chemical paradigm that guided the technological variants of the other trajectories. Investing in botanical systems that derive efficiency from diversity, from the synergy of their ecology and the resulting resilience, the AFSs, in their two variants, AFSs-F (silviagriculture) or AFSs-A (agroforestry), have gained economic and physical space. Throughout the period, establishments on other trajectories, mainly from the T1, migrated to it, displacing in its favour a productive collection of over 3 million hectares. An in-depth investigation of the future possibilities of this phenomenon would be advisable.

In turn, T3 has developed with livestock as its main component. This is a small livestock industry, which coexists in much more diverse productive systems than those of T4 – the employer focused on livestock, and therefore presented different productive attributes. The MPLd in 2017 was around 1/3 higher, and the land-labour ratio was approximately 1/3 lower than that of T4. Compared to other peasant trajectories, however, T3 was particularly outstanding because it presented the lowest MPLd and the highest land-labour ratio amongst them. Nevertheless, having started from a level similar to the others in 1995, it managed, in 2017, to reach the highest MPLb amongst the peasants. This was its strength.

Trajectory T1 presented itself as a trajectory in crisis, with the MPLb and MPLd falling in 2017. The basis of the difficulties would seem to be the mechanical-chemical intensification of the technological variant and its limitations in view of the particular ecology of the region. Lastly, mention should also be given to the fact that the influence of the attributes of each trajectory on the characteristics of regional development have changed correspondingly to the respective weights: trajectories T1, T2, T3, T4, T5 and T7, whose weights were 29%, 18%, 18%, 28%, 6% and 0% in 1995, by 2017 represented 9%, 14%, 13%, 35%, 6% and 23%.

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About the article

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APPENDIX A

A1 **Outline of techno-productive trajectories**

A1.1 **Block A of procedures: Qualification of product groups per se**

a) Qualification of product groups regarding social relevance: Separately, for the set of data of employers and peasants, the regression $Y_G = \sum_{k=1}^{7} \beta_k^{Y_G} * Y_{Gk}$ is calculated, where Y_G is the total *GPV* and Y_{Bk} is the GPV of the product group (*k* = 1 ... 7, according to the first column in Table A1). The β coefficients describe the way in which each *k* and, consequently, the production subsystem underlying it, participate in the variation of the total production Y_G of a production mode, constituting indications of its macro relevance. In this, as in the following solutions, the β are the Standardized Regression Coefficients of the linear regression expressed in z-scores, which are in the number of standard deviations around the mean (Bühl and Zöfel, 1996: 197-98; Backhaus *et al.*, 2000: 18-19; Hair *et al.*, 1998:147). A product group was considered socially relevant when $\beta_k^{Y_G} > 0{,}1$. If this occurs, the product group receives the "true" rating for attribute 1: T1 – otherwise, it is "false" for attribute 1: F1.

b) Qualification of *k* regarding private profitability: for each mode of production $Y_N = \sum_{k=1}^{7} \beta_k^{Y_N} * Y_{Gk}$, where Y_N is Net Income (*NY* = *GPV* – Total Production Costs) and Y_{Bk} the *GPV* of *k*. The values of the independent variables are the same as in the previous function, while the dependent variable corresponds to *NY*, *i.e.*, to the private remuneration of the establishments considered. Thus, it is a performance function, the regression of which describes how the considered *k* group acts on the remuneration of the stablishments: the same independent variable Y_{Gk}, which in the regression of the previous function influences $\beta_k^{Y_G}$ in the variation of *GPV*, through the current regression influences $\beta_k^{Y_N}$ in the variation of *NY* of establishments. Groups *k* whose *GPV* positively influence *NY* (the variation in their production directly influences total profitability) were considered consistent with private purposes if $\frac{\beta_k^{Y_N}}{\beta_k^{Y_G}} > 0$. If so, *k* receives the "true" qualification for attribute 2: T2 – otherwise, F2.

c) Qualification of k regarding investment: for each mode of production $I_F = \beta^I_{C_k} * C_k + \sum_{k=1}^{n} \beta^I_k * Y_{G_k}$, where I_F is the total investment declared in the census, Y_{Gk} the *GPV* of k, and C_k the volume of credit. The group was considered a source of investments when $\beta^I_1 > 0$. If this occurs, k receives the "true" rating for attribute 3: T3 – otherwise F3.

d) If a product group is qualified T1;T2;T3 it receives the general qualification class G1, indicating that it may have, during the period represented in this agricultural census, a key position in a technological trajectory, influencing its expansion in a consistent manner and with endogenous expansion capacity; if qualified, T1;T2;F3 receive the general class G2 indicating that it may have a main position and influence the expansion of a trajectory in a consistent manner, but without endogenous capacity for expansion; if T1; F2; F3, then it will be called G3, indicating that it may have a key position, however inconsistent and decadent; if F1;F2;F3, it is designated G4, and may be a decadent or experimental group; if F1; T2; T3, then it is G5, indicating the possibility of being an embryo of an emerging trajectory; if F1; F2;T3 then it is G6, being a subordinate group, with the role of partial financier of a trajectory; if T1; F2;T3, then it will be G7, indicating that it may be the main group in a trajectory, but with contested profitability and subordinated role as financier; finally, if F1;T2;F3, then it is G8, indicating an emerging group with no endogenous development capacity.

e) The regressions were found for the years 2006 and 2017 and, based on their parameters, each product group was qualified. The results are in Block A of Tables A1 and A2.

A1.2 **Block B of procedures: interaction patterns between product groups and definition of trajectories.**

a) Factor analyses were carried out for the years 2006 and 2017, the variables of which were the GPV of the 7 product groups involved in the previous analysis. There were two sets with information at a municipal level, one with data from peasant establishments and another from separate employer establishments according to IBGE criteria (Delgrossi, 2019). The process was conditioned to obtain six factors, in order to have the maximum representations of the data variance patterns. The results compose Block B of Tables A1 and A2.

b) Amongst the employer establishments, in 2006, the standard expressed in F1 (factor 1) was made up with F6 in a trajectory E.T4 (Employer.T4), dominated by cattle ranching, for which the main product was in the beef segment (meat), class G7 because of its low profitability. The pattern expressed in F2 is composed alongside that of F3 and F5 in Employer.T5 trajectory, led by permanent cultures, with a G2 attribute. Finally, F4 expressed a trajectory led by temporary cultures, class G1, designated Employer.T7. In 2017, similar patterns appeared: Employer.T4 results from the composition of F1 and F3; at T5 from F2 and F4 and at Employer.T7 from F5 and F6.

c) Amongst the peasant establishments, in 2006, the patterns presented by factors F1 and F4 suggested, in terms of composition, a peasant trajectory led by beef cattle (class G1) and dairy cattle (class G5) called Peasant.T3. F2, F3 and F6 suggested a trajectory led by non-timber extraction (class G1) and permanent crops (class G1), called Peasant.T2; F5 suggested a trajectory led by temporary cultures (G1) called Peasant.T1. In 2017, similar patterns were presented, F1 alone representing the trajectory Peasant.T3, led by beef cattle (G1) and dairy cattle (now G2), F2, F4 and F6 composed Peasant.T2, led by permanent (G1) and non-timber extraction (G2) and F3 and F5 in Peasant.T1, led by temporary crops (G2).

d) The factor loadings of each of these factors have been taken as variables of the databases used. So that, for each case, the factor with the highest loading indicates the trajectory to which the case (the annotated establishments) belongs. If in a line of information from the database of peasant establishments in 2017, the largest loading amongst all factors was that of F5, then that will be the case of trajectory Peasant.T1; if, in 2006, F2, then it will be in the Peasant.T2 trajectory.

Table A1 **Regression Coefficients β of the associated attributes of product groups, factorial loads of product group combinations for peasant and employer structures in the Northern Region, 2006**

Product groups (k)	**Block A**							**Block B**					
	Regression coefficients β[1]			**Attributes of k[1]**			**Class of product groups**	**Factor loadings**					
	Y_B	Y_L	**I**	**Macro or social relevance[1]**	**Private payoff[1]**	**Investment source**		**F1 (E.T4) (P.T3)**	**F2 (E.T5) (P.T2)**	**F3 (E.T5) (P.T2)**	**F4 (E.T7) (P.T3)**	**F5 (E.T5) (P.T1)**	**F6 (E.T4) (P.T2)**
Employer Production Mode													
1. Dairy cattle	0.024	0.064	0.018	F	T	T	G5	0.886	−0.092	−0.043	0.012	0.008	0.026
2. Beef cattle	0.468	−0.106	0.366	T	F	T	G7	0.868	−0.174	−0.099	0.055	−0.018	−0.042
3. Small animals	0.208	0.107	0.029	T	T	T	G1	0.136	0.256	0.738	−0.018	0.606	0.056
4. Perennial crops	0.159	0.035	−0.022	T	T	F	G2	0.134	0.391	0.662	−0.022	−0.623	−0.047
5. Annual cropps ehorticultura	0.817	0.535	0.133	T	T	T	G1	−0.059	−0.026	0.055	0.996	−0.007	0.021
6. Timber ext.	0.019	0.023	0.136	F	T	T	G5	0.108	0.734	−0.328	0.017	0.002	0.583
7. Non-timber ext.	0.015	0.011	−0.023	F	T	F	G8	0.086	0.741	−0.305	0.050	0.113	−0.578
8. Investment loan			0.051										
R^2	1.000	0.308	0.189	% of total variance 94.2%:				22.83	19.22	17.12	14.27	10.98	9.76

(continues on the next page)

Table A1 **(continuation)**

Product groups (k)	**Block A**							**Block B**					
	Regression coefficients β[1]			**Attributes of k[1]**			**Class of product groups**	**Factor loadings**					
	Y_B	**Y_L**	**I**	**Macro or social relevance[1]**	**Private payoff[1]**	**Investment source**		**F1 (E.T4) (P.T3)**	**F2 (E.T5) (P.T2)**	**F3 (E.T5) (P.T2)**	**F4 (E.T7) (P.T3)**	**F5 (E.T5) (P.T1)**	**F6 (E.T4) (P.T2)**
Peasant Production Mode													
1. Dairy cattle	0.043	0.020	0.138	F	T	T	G5	0.813	−0.397	0.133	0.273	0.027	0.089
2. Beef cattle	0.129	0.069	0.561	T	T	T	G1	0.856	−0.366	0.083	0.173	0.042	0.059
3. Small animals	0.051	0.022	0.055	F	T	T	G5	0.646	0.079	−0.008	−0.755	0.066	−0.033
4. Perennial crops	0.180	0.168	0.034	T	T	T	G1	0.477	0.572	−0.274	0.149	−0.439	−0.395
5. Annual cropps ehorticultura	0.843	0.869	−0.001	T	T	F	G2	0.232	0.480	−0.689	0.130	0.451	0.145
6. Timber ext.	0.075	0.075	−0.017	F	T	F	G8	0.115	0.601	0.602	0.113	0.424	−0.266
7. Non-timber ext.	0.101	0.104	0.010	T	T	T	G1	0.172	0.765	0.274	0.021	−0.261	0.492
8. Investment loan			0.259										
R^2	1.000	0.980	0.799		% of total variance 97.5%:			30.5	25.7	14.4	10.4	9.3	7.2

Source: IBGE, Agricultural Census 2006.

Table A2 **Regression Coefficients β of the associated attributes of product groups, factorial loads of product group combinations for peasant and employer structures in the Northern Region, 2017**

Product groups (k)	Block A							Block B					
	Regression coefficients β			Attributes of product groups[1]			Product class or group	Factor loadings (first five factors or main components)					
	Y_B	Y_L	I	Socially relevant[1]	Private positive payoff[1]	Investment source		F1 (E.T4) (P.T3)	F2 (E.T5) (P.T2)	F3 (E.T4) (P.T1)	F4 (E.T5) (P.T2)	F5 (E.T7) (P.T1)	F6 (E.T7) (P.T2)
Employer Production Mode													
1. Dairy cattle	0.019	−0.061	0.389	F	F	T	G6	0.829	0.087	0.041	0.074	−0.118	−0.322
2. Beef cattle	0.560	0.413	0.437	T	T	T	G1	0.878	−0.044	0.082	0.071	−0.032	−0.083
3. Small animals	0.365	0.343	0.023	T	T	T	G1	0.090	0.466	−0.668	−0.123	0.537	−0.156
4. Perennial crops	0.125	−0.347	0.055	T	F	T	G7	0.076	0.760	0.025	0.156	−0.421	0.464
5. Annual cropps ehorticultura	0.595	0.351	−0.017	T	T	F	G2	0.412	−0.280	−0.015	−0.084	0.398	0.755
6. Timber ext.	0.006	0.015	0.014	F	T	T	G5	−0.052	0.389	0.742	−0.163	0.505	−0.114
7. Non-timber ext.	0.049	0.054	−0.007	F	T	F	G8	−0.103	−0.025	0.026	0.956	0.270	−0.018
8. Investment loan			0.152										
R^2	1.000	0.567	0.813	% of total variance 94.2%:				23.7%	14.8%	14.4%	14.3%	13.8%	13.3%

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Table A2 **(continuation)**

Product groups (k)	**Block A**							**Block B**					
	Regression coefficients β			**Attributes of product groups**[1]			**Product class or group**	**Factor loadings (first five factors or main components)**					
	Y_B	Y_L	**I**	**Socially relevant**[1]	**Private positive payoff**[1]	**Investment source**		**F1 (E.T4) (P.T3)**	**F2 (E.T5) (P.T2)**	**F3 (E.T4) (P.T1)**	**F4 (E.T5) (P.T2)**	**F5 (E.T7) (P.T1)**	**F6 (E.T7) (P.T2)**
Peasant Production Mode													
1. Dairy cattle	0.210	0.134	−0.016	T	T	F	G2	0.840	−0.357	0.018	0.254	0.190	−0.027
2. Beef cattle	0.463	0.434	0.139	T	T	T	G1	0.899	−0.268	0.004	0.165	0.127	−0.055
3. Small animals	0.079	0.054	−0.004	F	T	F	G8	0.688	0.181	−0.004	−0.472	−0.316	0.412
4. Perennial crops	0.307	0.321	0.004	T	T	T	G1	0.444	0.662	−0.176	−0.021	−0.309	−0.487
5. Annual cropps ehorticultura	0.382	0.440	−0.011	T	T	F	G2	0.154	0.701	0.290	−0.280	0.567	−0.005
6. Timber ext.	0.032	0.015	−0.005	F	T	F	G8	0.025	0.158	0.912	0.286	−0.243	0.031
7. Non-timber ext.	0.263	0.299	−0.005	T	T	F	G2	0.015	0.671	−0.333	0.574	0.006	0.331
8. Investment loan			0.049										
R^2	1.000	0.965	0.025		% of total variance 97.5%:			31.6%	23.4%	15.1%	11.5%	9.0%	7.4%

Source: IBGE, Agricultural Census 2017.

APPENDIX B

B1 **Delimitation of technological variants**

B1.1 **Calculation of variables indicating technological variants**

Technological variant signifies the trajectory taken by a combination of productive means based on a paradigmatic technological orientation adapted to natural and institutional circumstances. Thus, within the mechanical-chemical paradigm, the solutions are considered, to a greater or lesser intensity, in terms of the use of mechanics and/or chemistry, in relation to, for example, the institutional conditions for obtaining work and land. If there is plenty of land and little work, the tendency is for a greater mechanical intensification to occur; if, to the contrary, there is plenty of work and little land, it is possible that there will be a greater intensification of chemistry. Intermediate routes, in turn, are possible. To verify the occurrence of these possible trajectories, the following variables have been created, based on the possibilities offered by the 2006 and 2017 censuses:

B1.1.1 *For all establishments:*

a) Chemical Intensity Fertilizers (CIFerts) = Costs with fertilizers $/Total used landHa;
b) Chemical Intensity Pesticides (CIPest) = Costs with Pesticides $/Total used landHa;
c) Mechanical Intensity Inputs (MIInps) = Fuel Costs $/Total used landHa;
d) Mechanical Intensity Investments (MIInvests) = Investments in Machinery and Equipment $/Total used landHa;
e) Labour Intensity (LI) = Total WorkersHDAno/Total used landHa.

B1.1.2 *For establishments with livestock:*

The data from the aforementioned censuses enable us to assess the intensity of the mechanical-chemical pattern directly in the herd and directly in the pasture and, even more, to verify the relationship between these two fundamentals. Thus, the following variables were created:

a) Chemical Intensity Livestock (CILS) = Costs with chemical inputs for cattle $/HerdCab;
b) Pasture Intensity (PstI) = Total spending on pastures $/ExtensionPastHa;
c) Herd Intensity (HerdI) = Total expenses with herd $/HerdCab; and
d) Herd-Pasture Intensity (HPI) = HerdCab/ExtensionPastHa.
e) Total spending on pastures that appeared in the census involved draining, reforming and improving pastures. The variable PstI indicated the intensification of capacity and the improvement of pasture, since such expenses increase per unit area of pastures. If the expenses were for the formation of pastures of the same quality (with the same technology), PstI did not grow because the denominator of the fraction that gave rise to it grew in the same proportion as the numerator; if they were spent on improvement, PstI grew because the denominator remained the same for a larger numerator; and so on. The same reasoning must also prevail when dealing with the variable HerdI.

B1.1.3 *To assess the technical evolution of systems based on permanent crops and the use of non-timber forest resources (extraction gathering), other variables were shown to be relevant.*

These were:

a) Forest Intensity (FI) = Total forest used/Total Used Area;
b) Permanent Crops and Forestry Intensity (PCFI) = Total investments in permanent crops and forestry $/AreaUsedHA.

B1.2 **Delimitation of technological variants**

Factorial analyses were performed with these new variables for each trajectory delimited by the methodology described in Appendix I, without fixing the number of factors and using the rotated factors to improve the definition of standards. The results are shown in Table B1.

B1.2.1 *For trajectories dominated by temporary agriculture, the patterns were described by the combination of three components (characteristics):*

a) Chemical Intensity (CI), informed by the loads of the variables CIFerts and CIPest;
b) Mechanical Intensity (MI), informed by MIIns and MIInvest, and
c) Labour Intensity (LI), reported by ITlabour.
d) CI + (= established attribute) were considered when the two variables related to chemistry had positive charges and were above 0.2; CI- (= nonexistent attribute) when both variables had negative charges and CI0 (partial, initial) when at least one of the variables had a charge less than 0.2. The same criteria prevailed for MI. For IT, when above 0.2, intensive work per unit area; below that, the opposite.

B1.2.2 *For trajectories dominated by livestock:*

a) Pasture Improvement (PI) reported by the variable PstI;
b) Herd Improvment (HI) informed by the variables CIL and HerdI;
c) Load Capacity (LoadC), informed by the variable HPI;
d) PstI + were considered if the load of the variable PI was greater than 0.2; PstI- if the PI load was less than zero; PstI0 if the PI load was greater than zero and less than 0.2; HerdI + when the loads of CIL and HI were greater than 0; HerdI- when the loads of CIL and HI were less than 0; HerdI0 when, for one of the two variables, the loads were less than 0; Load + will be considered when the load of the Herd-Load Intensity variable was greater than 0.2; Load – when less than 0; and LoadC0 when between 0 and 0.2.

B1.2.3 *For trajectories dominated by non-timber forest production and permanent crops and silviculture, the following were considered.*

a) The AFSs dominated by permanent PCFI crops greater than 0.2 and FI less than 0.2;

b) AFSs dominated by PCFI forest extraction less than 0.2 and FI greater than 0.2;

The results are shown in Table B2.

Table B1 **Definition of technological variants of the techno-productive trajectories**

	2006		2017	
	Factors/variants		Factors/variants	
	F1	**F2**	**F1**	**F2**
Technologial Trajectory Peasant.T1				
	$(CI^{0}MI^{0}LI^{-})$	**$(CI^{0}MI^{+}LI^{+})$**	**$(CI^{+}MI^{+}LI^{-})$**	**$(CI^{+}MI^{-}LI^{+})$**
CIFerts	**.927**	−.101	**.386**	**.598**
CIPest	−.054	**.572**	**.925**	**.242**
MIIns	.054	**.819**	**.879**	−.075
MIInvests	**.906**	**.207**	**.939**	.058
LI	.143	**.745**	−.138	**.844**
Variance	37%	29%	55%	21%
Technologial Trajectory Employer.T7				
	$(CI^{0}MI^{0}LI^{+})$	**$(CI^{0}MI^{0}LI^{-})$**	**$(CI^{+}MI^{0}LI^{-})$[7]**	**$(CI^{0}MI^{-}LI^{+})$**
CIFerts	**0.539**	−0.197	**0.976**	−0.035
CIPest	0.140	**0.810**	**0.859**	**0.158**
MIIns	**0.922**	0.157	**0.950**	−0.044
MIInvests	−0.115	**0.829**	−0.045	−0.602
LI	**0.888**	0.108	−0.015	**0.810**
Variance	40%	28%	52%	21%
Technologial Trajectory Peasant.T2				
	AFS-A	**AFSs-F**	**AFSs-F^{-}**	**AFSs-A**
MIIns	**0.926**	0.003	.108	−.125
MIInvests	**0.928**	0.024	−.099	.089
FI	**0.173**	**0.787**	**.881**	−.160
PCFI	**0.224**	−0.644	**.708**	**.455**
LI	0.146	−0.065	−.006	−.932
Variance	37%	21%	28%	20%

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Table B1 **(continuation)**

	2006		**2017**	
	Factors/variants		**Factors/variants**	
	F1	**F2**	**F1**	**F2**
Technologial Trajectory Employer.T5				
	Permanent		**Permanent**	
MIIns	0.011		0.026	
MIInvests	0.000		−0.254	
PCFI	**0.905**		**0.791**	
L	0.037		−0.467	
Variance	32%		67%	
Technologial Trajectory Peasant.T3				
	($PI^{+}HI^{-}LoadC^{+}$)	**($PI^{-}HI^{0}LoadC^{-}$)**	**($PI^{-}HI^{+}LoadC^{+}$)**	**($PI^{+}HI^{0}LoadC^{+}$)**
CIL	−0.113	−0.714	**.780**	−.290
PstI	**0.935**	0.061	−.516	**.684**
HerdI	−0.091	**0.743**	**.381**	**.743**
HPI	**0.934**	−0.031	**.676**	**.438**
Variance	44%	27%	37%	32%
Technologial Trajectory Employer.T4				
	($PI^{+}HI^{-}LoadC^{+}$)	**($PI^{-}HI^{0}LoadC^{-}$)**	**($PI^{+}HI^{+}LoadC^{+}$)**	**($PI^{-}HI^{0}LoadC^{+}$)**
CIL	−0.251	**0.712**	**0.638**	−0.140
PstI	**0.708**	−0.206	**0.328**	−0.702
HerdI	−0.271	−0.682	**0.640**	0.141
HPI	**0.706**	**0.219**	**0.325**	**0.704**
Variance	28%	26%	26%	26%

Source: IBGE, Agricultural Census 2006 and 2017.

Notes: 1) CI = Chemical Intensity; 2) MI = Mechanical Intensity; 3) Total: Total of the trajectory; 4) PI = Pasture Improvement; 5) HI = Herd improvement; 6) AFSs-F = AFSs with the presence of forest management; 7) AFSs-A = Artificially developed AFSs; 8) "+" after the atribute = Attribute clearly verified; 9) If "–" = attribute clearly absent; 10 is "0", an uncertain attribute.

Table B2 **Name Gross Value of Production, Total Area and Agriculture, Total Employed Personnel, Monetary Productivity of Labour and Land and Land-Labour Ratio of the agrarian economy of the North Region, 2006 and 2017, at R$ 1,000, at 2019 prices.**

Peasant			$CI^0MI^0LI^-$	$CI^0MI^+LI^+$	Total	AFSs-A	AFSs-F	Total	$PI^+HI^-LoadC^+$	$PI^-HI^0LoadC^-$	Total
	2006	Establishments	46,453	30,332	76,785	31,817	106,513	138,330	63,116	134,435	197,551
		Total GPV	1,509,837	848,822	2,358,659	792,654	2,623,874	3,416,528	1,004,138	3,150,391	4,154,529
		Total Area	1,731,492	1,031,088	2,762,580	1,278,566	3,223,597	4,502,163	2,909,582	6,436,949	9,346,531
		Total Used Land (TUL)	760,053	544,104	1,304,156	655,926	1,630,142	2,286,068	1,454,264	3,900,991	5,355,255
		Total Occupied Personnel (TOP)	105,244	78,721	183,966	76,922	266,013	342,935	156,787	328,251	485,038
		MPLb=GPV/TOP (R$ 1.000)	14.3	10.8	12.8	10.3	9.9	10.0	6.4	9.6	8.6
		MPLd=GPV/TUL	2.0	1.6	1.8	1.2	1.6	1.5	0.7	0.8	0.8
		LLR=TUL/TOP	7.2	6.9	7.1	8.5	6.1	6.7	9.3	11.9	11.0
			$CI^+MI^+LI^-$	$CI^+MI^-LI^+$	Total	AFSs–A	AFSs–F	Total	$PI^+HI^0LoadC^+$	$PI^-HI^+LoadC^+$	Total
	2017	Establishments	92,539	47,797	140,336	112,195	87,660	199,855	39,733	76,515	116,248
		Total GPV	1,954,861	1,223,339	3,178,199	2,932,751	1,995,652	4,928,402	1,641,782	2,787,266	4,429,048
		Total Area	2,770,484	1,596,090	4,366,574	4,525,789	3,461,466	7,987,255	2,089,760	5,323,613	7,413,373
		Total Used Land (TUL)	1,151,777	820,251	1,972,028	2,220,770	1,650,114	3,870,884	1,457,330	3,490,902	4,948,232
		Total Occupied Personnel (TOP)	202,468	102,233	304,701	234,962	192,599	427,561	75,206	144,982	220,188
		MPLb=GPV/TOP (R$ 1.000)	9.7	12.0	10.4	12.5	10.4	11.5	21.8	19.2	20.1
		MPLd=GPV/TUL	1.7	1.5	1.6	1.3	1.2	1.3	1.1	0.8	0.9
		LLR=TUL/TOP	5.7	8.0	6.5	9.5	8.6	9.1	19.4	24.1	22.5

					EmployerT4		EmployerT5			EmployerT7	Total of
Employers			$PI^{+}HI^{-}LoadC^{+}$	$PI^{-}HI^{0}LoadC^{-}$	Total	Plantation	Total	$CI^{0}MI^{0}LI^{+}$	$CI^{0}MI^{0}LI^{-}$	Total	North Region
	2006	Establishments	26,008	10,480	36,488	22,194	22,194	1,714	2,716	4,430	475,778
		Total GPV	3,661,937	896,627	4,558,564	2,062,607	2,062,607	679,749	1,289,641	1,969,390	18,520,277
		Total Area	20,070,485	5,242,556	25,313,041	9,740,326	9,740,326	1,913,492	1,957,639	3,871,131	55,535,772
		Total Used Land (TUL)	11,473,626	2,615,149	14,088,775	4,990,402	4,990,402	1,043,417	1,112,366	2,155,783	30,180,438
		Total Occupied Personnel (TOP)	142,681	34,901	177,583	75,684	75,684	5,702	9,222	14,924	1,280,130
		MPLb=GPV/TOP (R$ 1.000)	25.7	25.7	25.7	27.3	27.3	119.2	139.8	132.0	14.5
		MPLd=GPV/TUL	0.3	0.3	0.3	0.4	0.4	0.7	1.2	0.9	0.6
		LLR=TUL/TOP	80.4	74.9	79.3	65.9	65.9	183.0	120.6	144.4	23.6
			$PI^{+}HI^{+}LoadC^{+}$	$PI^{-}HI^{0}LoadC^{+}$	Total	Plantation	Total	$CI^{+}MI^{0}LI^{-}$	$CI^{0}MI^{-}LI^{+}$	Total	Total of North Region
	2017	Establishments	20,906	36,470	57,376	16,488	16,488	9,313	7,241	16,554	546,857
		Total GPV	3,001,335	9,156,892	12,158,226	2,103,361	2,103,361	4,495,154	3,336,009	7,831,162	34,628,399
		Total Area	10,735,237	21,400,854	32,136,091	3,863,482	3,863,482	5,380,171	4,066,413	9,446,584	65,213,359
		Total Used Land (TUL)	6,316,582	12,241,292	18,557,874	1,652,146	1,652,146	2,803,579	2,331,498	5,135,077	36,136,241
		Total Occupied Personnel (TOP)	109,184	136,416	245,600	66,710	66,710	39,641	30,614	70,255	1,335,015
		MPLb=GPV/TOP (R$ 1.000)	27.5	67.1	49.5	31.5	31.5	113.4	109.0	111.5	25.9
		MPLd=GPV/TUL	0.5	0.7	0.7	1.3	1.3	1.6	1.4	1.5	1.0
		LLR=TUL/TOP	57.9	89.7	75.6	24.8	24.8	70.7	76.2	73.1	27.1

Source and notes: See Table B1.