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AGRARIAN DYNAMIC AND CO2 BALANCE IN AMAZON

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AGRARIAN DYNAMIC AND CO_2 BALANCE IN AMAZON[1]

Francisco de Assis Costa[2]

Resumo:

Na discussão sobre o estabelecimento do fornecimento de bens ambientais, o papel de vegetações secundárias como "capoeiras" tem recebido pouca atenção. Assim, o esforço alocado para a compreensão dos processos que as geram, particularmente aqueles de natureza econômica, são insignificantes. As "capoeiras" constituem um componente muito importante da paisagem rural da Amazônia e são essenciais para o balanço de CO2. No Censo Agropecuário de 1995, as "capoeiras" foram responsáveis por 4,5 milhões de hectares na Amazônia, o que representa 16,5% da terra em operação e cerca de 8% de toda a terra de propriedade naquele ano. Infelizmente, o último Censo de 2006 não avalia os dados de variáveis comparáveis. De modo que, com base nesses dados do Censo Agropecuário 1995, estudos anteriores indicaram que 24% das "capoeiras" referem-se às formas insustentáveis de agricultura como a agricultura itinerante e os restantes 76% correspondem a terras abandonadas degradadas por funções agrícolas. Este trabalho demonstra a impropriedade desta conclusão, indicando que cerca de metade dessas terras se relacionam com usos agrícolas mais intensivos e promissores do que os seus precedentes. Além disso, observou que ao longo dos anos esses usos constituem etapa significativa em um caminho iniciado por agricultura itinerante liderada por camponeses locais. Essa dinâmica não é trivial na produção de bens ambientais e deve ser acompanhada de perto pelos gestores públicos.

Palavras-chave: Amazônia. Balanço de CO_2. Dinâmicas agrárias.

Abstract:

In the discussion about the establishment of the supply of environmental goods, the role of secondary vegetations like “capoeiras” has received little attention. Thus, the effort allocated to understanding the processes that generate them, particularly those of economical nature, are negligible. The “capoeiras” constitute a very important component of the Amazonian rural landscape and are essential for the CO2 balance. In Agricultural Census of 1995 the "capoeiras" accounted for 4.5 million hectares in Amazon, representing 16.5% of the land in operation and about 8% of all owned land in that year. Unfortunately, the last Census of 2006 did not upraise the data of comparable variables. So that, based on those data of 1995 Agricultural Census, former studies stated that 24% of “capoeiras” relate to the unsustainable forms of agriculture like shifting cultivation and the remaining 76% correspond to abandoned lands degraded by agricultural functions. This paper demonstrates the impropriety of that conclusion, indicating that about half of these lands relate to more intensive and promising agricultural uses than their precedent ones. In addition, observed through the years those uses constitute significant stage in a path started by shifting cultivation led by local peasants. Such a dynamic is not trivial in the production of environmental goods and should be closely watched by the policy makers.

Keywords: Amazon. CO2 Balance. Agrarian Dynamics.

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1. INTRODUCTION

The development of regulations that limit gas emissions is creating a demand for environmental assets, thus forming a new market for these assets. The expectations of development of new sources of clean energy and of decrease in costs of the current production of clean energy induced by the change in its relative price are affecting the supply side. This shift seems to be consolidating the recognition of the importance of original forestry biomes, especially the tropical ones, capable of either sequestrating carbon (sink CO_2) or maintaining biodiversity. Objectively, it seems inevitable to add measures in the Kyoto Protocol (KP), which in its original version does not include any mechanism on forest conservation (EBELING, 2006).

At the same time, the agricultural systems are gaining importance. These systems, formerly seen almost exclusively as pollutant and tending to reduce biodiversity, now, due to the demand created by this new market, are viewed as important given their ability to sink carbon and replenish the biological complexity of the planet. A subset of these systems based on perennial cultures and on agroforestry compositions (STERN, 2007, p. 603-621) is highlighted by a recent Stern Review as potentially consistent with forestry conservation as a means to reduce emissions. These activities, while reducing the pressure imposed on forests and creating mechanisms to absorb carbon, will increase supply and thus decrease the cost of the environmental asset – either stabilization or reversion of climate changes – and will make the mitigation strategies more cost effective.

It is, thus, most urgent to clarify, as far as the Brazilian Amazonia and its rural sector are concerned, the terms of the problem and its quantitative expressions. In this regard, this paper intends to contribute, firstly, assessing the supply and demand of the region regarding one of the segments of this new market: CO_2 emissions.

On the other hand, by reasons of both theoretical (to offer a perception of reality as adhering as possible) and mediating (to provide for better direction of future negotiations for correcting asymmetries between involved agents) nature, the calculations will seek to:

- guarantee an analytical view of the interaction between the economic processes and natural bases, what means that:

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- Natural resources from the Amazon are key, fund elements of its economy, and their transformation and use are entropic[3] processes and should be understood and treated as such.
- An entropic conception of the economy will allow the appropriate treatment of the negentropic dynamics, anti-entropic property of living systems open to energy entry, as is the case we will explore (GUHA, MARTINEZ-ALIER, 2006, p. 175)

- distinguish the heterogeneity of the agents in the economic processes (and its environmental implications), recognizable in the heterogeneity of the bases (objective: either natural or social/institutional base) and rationalities (subjective: diffuse and systematic) and their interactions. These structural differences correspond to the asymmetrical access to both natural and social resources that will reflect on the specific forms of contribution to the environmental disorganization indicated in the balances of CO_2 emissions. This matter has been discussed by Georgescu-Roegen in a less known work (1960) and emphatically by Guha and Martinez-Alier (2006) for wide contexts and by me for the Amazonian context (COSTA, 2005).
- evaluate inequalities created by the development of this new market. Existing literature shows that the use of natural resources promotes social (ALTVATER, 1993) and regional (BUNKER, 1985) inequalities. The wealth created by exploring a natural resource is usually transferred to regions other than the area explored, and this latter is left with the results of the entropy created.

In addition to this introduction, this paper is divided into four chapters: in Chapter 2 we discuss the production systems and their characteristics. In Chapter 3 we develop the methodology that will connect these production systems to emissions of CO_2 and present a historical series of this relationship - from 1990 to 2005. In Chapter 4 we discuss the results and, at last, we conclude by presenting strategic paths for a new policy for the development of Amazonia.

[3] "Any material process consists in the transformation of some materials into others (the flow elements) by some agents (the fund elements)…" and "… there is no substitution between flow and fund factors."(GEORGESCU-ROEGEN, 1979, p. 98; 1983, p.23 - 28)

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2. AN ESSENTIAL COMPONENT OF THE PRODUCTIVE SYSTEMS OF THE AGRARIAN AMAZON

Forest areas are incorporated into the productive system as areas of forestry exploration through logging and non-logging activities, as agricultural lands, and as grasslands. Through these last two means of exploration, these areas can become “Capoeiras.” “Capoeiras” are areas with secondary vegetation that are either temporarily or permanently removed from the production process. It is of fundamental importance to understand the relationship between these three forms of exploration, their co-existence and their future for understanding the dynamics of the rural sector and its entropic and negentropic processes.

“Capoeiras” are areas of land at different stages of natural regeneration after having been radically altered by human intervention[4]. “Capoeiras” are an important component of the rural landscape in the Amazon. The current official accounting of deforestation[5], measured by “Gross Deforestation Rate”, is the amount of areas cleared with “low cut” in the Amazon. This rate grows each year, increasing the environmental liabilities. Since this measurement does not account for the "Capoeiras", they constitute an invisible environmental asset. The calculation of a “Net Deforestation rate” should consider the "capoeiras", once areas that are either recuperated or under regeneration have significant value. According to the last census, carried out in 1995, the areas of “Capoeiras” in the Northern Region[6] comprised an area of 4.5 million hectares. It corresponds to 8% of the entire area of the region accounted in that year and to 17% of the whole areas in use as either natural or planted grassland (pastures), as permanent or temporary cultures or as planted forests. It also corresponds to 14% of all deforested areas.

The different notions of “Capoeiras”

In the core of the environmental debate and its reflections on the Amazon, two distinct remarks about the “Capoeiras” have emerged. The first one states that the “capoeiras” are important only as expression of the elimination of the forest by agriculture and as indicator of

[4] For a more detailed explanation of the different type of Capoeira and redefinition of this land use in the future see Davidson et alii, 2007; Zarin et alii, 2005; Leal, Vieira, Kato, 2004; Vieira, Proctor, 2007; Kato, Sá, Kato, Brienza Junior, 2004; Kato, Kkato, Sá, Figueiredo, 2004; Uhl, 1987; Hhl, Jordan, 1984; Vielhauer, Kanashiro, Sá, 1997; Kato, Kato, Denich, Vlek, 1999.

[5] The deforestation calculations done by PRODES, a team of INPE. For additional information about calculation methods, see Krug (2001, p. 92-93).

[6] Unless otherwise noted, the statistics presented are for the North region – Pará, Amazonas, Roraima, Rondônia, Acre, Amapá, and Tocantins, This region will be also referred as Amazonian Region or just Amazon. The Legal Amazon also includes the states of Mato Grosso and the Northwest of Maranhão state.

the failure of agrarian activities. The second remark emphasizes the importance of the “capoeiras” as a reforestation area that is restoring ecological properties of the tropical forest. The first observation presents the “capoeiras” as a liability, while the second one views it as an asset. The arguments used to support the liability view are that "capoeiras" are associated with practices such as *shifting cultivation*. These practices are economically inefficient leading to a non-sustainable use of the natural resource. The use of "capoeiras" would only be justified for agents excluded from other areas of lower opportunity costs for them. These agents would be moving to the “speculative frontier” of the Amazon Region. This is the position defended by Schneider (1995, p.15-32), followed by Margulis (2003).

Margulis argues further that the “speculative frontier” would generate a “consolidated frontier” economically sustainable only in areas with intermediate rainfall, suitable for a larger scale business ranching activities. According to Margulis, in areas of high humidity, where efficient ranching activities would fail, the only thing left, after the inexorable failing of *shifting cultivation*, would be abandoned lands and subsequent "capoeiras". The Bragantinha region, located in the Northeast of Pará would be a perfect example of this effect. In this region Margulis, in agreement with Chomitz and Thomas (2000) and with Schneider and the Imazon team (SCHNEIDER, ARIMA, VERÍSSIMO, BARRETO, SOUZA JR., p. 2000), notes: “the irrefutable evidence that few economical activities can resist an intense rain fall and only logging activities make sense in these areas.” (MARGULIS, 2003, p. 65). In summary, the *new* "capoeiras" are transitory elements of the landscape, once bound to an inefficient economy, whereas the old ones represent abandoned lands, the effectuation of predicted inefficiency, being thus indicators of decadency and incapacity.

The second remark, which highlights the importance of the "capoeiras" associated to *shifting cultivation* as an asset, evolved from botanical, biological and agronomic researches developed on the same region mentioned above. These researches are showing that the "capoeiras" have species diversity, complex root system, and dense biomass, properties that are so more effective, the less intensive and the shorter in time has been the agriculture activity, and the longer the time elapsed since the cessation of the use. (VIEIRA *et alii*, 1996; PEREIRA, VIERA, 2001; VIELHAUER *et al*, 1997; SA *et al*, 2004).

On the other hand, economic researches on the agrarian dynamic of this same region showed that statistically there was no evidence of loss in productivity of shifting cultivation. Historically it could be shown that there was a drastic reduction of production during the 30’s

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and 40’s, but after that follows a period of productivity stabilization in the region, so that the cyclical profitability crisis observed from the 50’s on was caused rather by socio-economic factors than by ecological ones (HURTIENNE, 2001).

Differently than the former, the later results indicate that "capoeiras" linked to *shifting cultivation* would be technologically consistent since they were able to maintain their physical function in the systems (grounding technical relations). They would have large capacity for deterring leaching and for allowing agricultural production on the same area indefinitely. Following this, one would be allowed to think further that they could provide, in an equally consistent and permanent way, environmental services through carbon sequestration, biodiversity maintenance, and maintenance of the rainfall regimen in addition to their traditional agricultural production, corresponding, thus, to the new demand generated by growing environmental and climate change concerns.

However, things are not that simple. As a mater of fact, if one looks closer at different sub-regions within a limited timeframe, would be able to see that the reality of *shifting cultivation* is dynamical. So that various paths of agricultural intensification evolve out of it, either as adaptive solutions to its *crisis* or as induced changes produced by the public policies and agricultural incentives (COSTA, 2000a). There is not a steady *shifting cultivation*. Besides, although the results of the dynamics led to dominant solutions characterized by diversified systems, where perennial and semi-perennial cultures (oranges, black pepper, passion fruit, etc.) tended to substitute the shifting cultivation (COSTA, 1996ª e 1997), there are solutions toward more simplified systems as well and situations of failure and decadence.

These findings raise important questions regarding the two remarks explained above. Regarding the first one, they indicate that the increase in both size-area and duration of the "capoeiras" may mean economical development. Therefore, old "capoeiras" that are treated as failing agricultural systems by the first group of authors may be associated with the intensification of agriculture, and hence with adaptive dynamics with more efficient agricultural practices, which, for requiring less area, would displace systems that are more extensive. We will discuss this further on 2.1.

Regarding the second remark, they indicate that the "capoeiras" can be either a product of shifting cultivation, as its constitutive part, or a product of the denial of shifting cultivation. Thus, they can represent distinct ways of creation, which in either case are relevant to the way they will provide environmental equilibrium. We will discuss this further on 2.2.

2.1. The structural view of "capoeiras": empiric and theoretical implications

Dynamic economic settings form "capoeiras" in the Amazon. These settings are characterized by the diversity of the agents, production means, and technology capability (COSTA, 2005 – in the broader sense as defined by COSTA, 2008). The heterogeneity notions discussed here includes the intrinsic differences of the agents – specifically those molded after structural constraints of the production means following the tradition of Chayanov (1923), Tepicht (1974) and Costa (1989, 1995, 2007[a], 2007b). It will also include the "…different hypotheses or beliefs or action..." of agents of a same nature as indicated by Arthur (1994a).

According to this perspective, the evaluation of agrarian dynamic in the Amazon is based on the internal movement and competitive and cooperative interactions between two production forms. The Peasant production form, where the farm household is the basic structure, relies on relatively small land plot. The Corporative production form is characterized by major use of wage labor and usually large parcels of land (COSTA, 2000 e 2006).

The diversity of agents and their production means is related to a variety of technologies that can be used. By technology, in this context, we mean the set of techniques and procedures that mediate labor and nature, made of both tangible and intangible apparatus inherited, on the one hand, from past labor processes, which, therefore, constitute "...organs of the human brain, created by the human hand; the power of knowledge, objectified." (MARX, 1953, p. 706); inherited, on the other hand, as a paradigm, i.e., as cognitive structure, "… as a 'model' or a 'pattern' for solution of selected technological problems (DOSI, 2006, p. 22 e 23).

2.2. The "capoeiras" as represented in the Census Statistics

The agricultural Census of 1995-96 presents two categories of secondary vegetation. They are: "*Terras em Descanso*" (Areas under Rest), related to areas that are not used for up to four years and "*Terras Produtivas não Utilizadas*" (Unused Agricultural Areas) referring, to areas not used for more than four years. Unfortunately, the last Census of 2006, did not uprise the data of comparable variables. So that Chart 1 refers to Census of 1995-96 and presents the values assumed by these variables in the Northern Region. In total (Ac) they are 4.5 million hectares: 1.1 million hectares of lands resting for up to four years and 3.4 million hectares of

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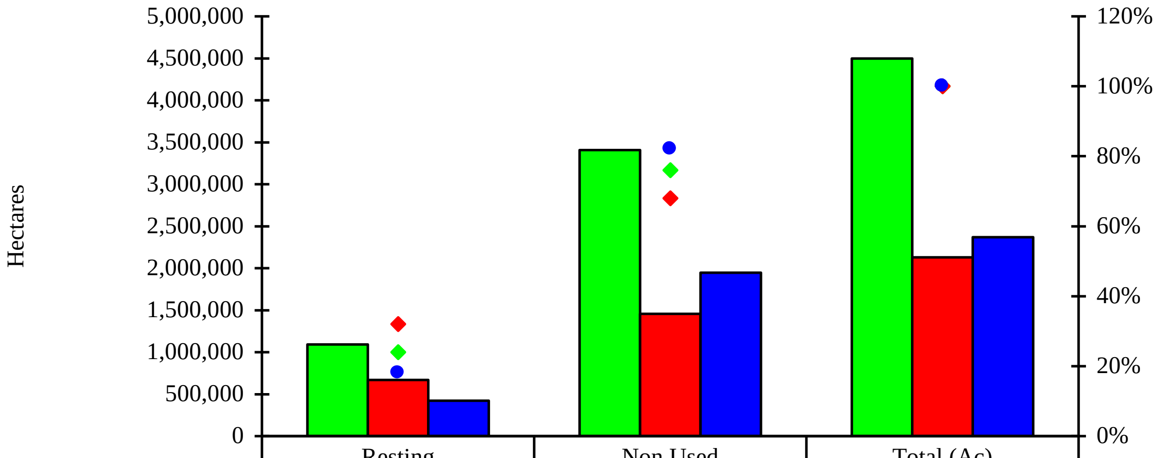
lands not used for more than 4 years. Considering the production modes, peasants units accounted for about 0.7 and 1.5 million hectares (32% and 68%) respectively, and the units of corporative production for 0.4 and 1.9 millions hectares (18% and 82% of the total).

2.3. "Capoeiras": Time and Space

In establishing such a rigid limit for classifying lands – either maximum of four years to the category of “resting lands in agricultural use” or more than four years without use to classify as “suitable but not used areas” – the Census induces to several errors when one wishes to evaluate productions systems with "capoeiras". Chomitz and Thomas (2000), for example, assumed that lands classified as “Unused” by IBGE are in fact what this designation suggests: lands without utilization or function or abandoned lands. Thus, the drastic thesis of Chomitz and Thomas is that these lands, in total and generically, are indicators of both economically and ecologically non-sustainable production systems (SCHNEIDER, ARIMA, VERÍSSIMO, BARRETO, SOUZA JR., 2000).

Chart 1 – Areas under Rest and Unused Agricultural Areas in the 1995-96 Census, by Agent



	Resting	Non Used	Total (Ac)
Absolut Total (Ac)	1,091,111	3,405,183	4,496,294
Peasant	670,864	1,457,087	2,127,951
Corporative	420,247	1,948,096	2,368,343
Total (%)	24%	76%	100%
Peasant (%)	32%	68%	100%
Corporative (%)	18%	82%	100%

Source: IBGE – Agricultural Census – All States of North Region, 1995-96. Tabulation by the author

We have reasons to question this conclusion, as stated below:

The land's resting time is a variable that depends of external conditions. Ximenes and Van Dyle (2000:50) proposed the relation time-space in the resting agriculture as:

$$\frac{A}{A_a} = \frac{t}{u} \quad (1)$$

The total area required to make the system work, represented by (A), is to the planted Area (Aa) as the complete cycle of rest and use (t) is to the time that is possible to plant in the same area (u). If we consider that the system's total need of land can be represented as the planted area (Aa) plus the resting area (Ac), and the total time as the number of years that is possible to plant in the same area (u) plus the number of years of development of "capoeira" until it is ready to accomplish its active function (n), then we could re-write the equation (1) as follows:

$$\frac{A_a + A_c}{A_a} = \frac{u+n}{u} \;\therefore\; \frac{A_c}{A_a} + 1 = \frac{n}{u} + 1$$ And then,

$$n = u \bullet \frac{A_c}{A_a} \quad (2)$$

If we assume additionally that $A_c = \frac{P_c}{n.p_c}$ (3), as we understand that the area that is decided to be kept as *capoeira* is a result of the own *capoeira's* production Pc. This production can be a volume of biomass or a set of functions such as producing logs for fire, logging for mills, for construction, or more importantly to sequestrate carbon and keep biodiversity. Total P_c represents the availability of the *capoeira* to deliver any of the required function in the production system, which is gradually achieved by an annual incremental productivity by hectare with average p_c during the time *n* already defined. Further, we might consider that $A_a = \frac{P_a}{u.p_a}$ (4) because this biomass volume or set of functions of the *capoeira* is required for an agricultural production, *Pa,* derived from an agricultural average productivity hectare/year of p_a for a rotation time, also above defined, *u*. In view of this, relation (2) could be rewritten as $n = u\left(\frac{P_c}{n.p_c} \Big/ \frac{P_a}{u.p_a}\right)$ and therefore as:

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$$n = u\left(\frac{p_a}{p_c} \bullet \frac{P_c}{P_a}\right)^{1/2} \qquad (5)$$

The relation (5) shows that for the same proportionality Pc/Pa, the age of the *capoeira* (n) varies directly with the productivity per unit of agricultural land and with the duration of planting in the same area. By the age of *capoeira*, we mean the time necessary for the *capoeira* to fulfill its potential. In addition, the proportion above is inversely related to the *capoeira's* productivity. Thus, the duration "n" of the *capoeira*, as a dependent variable, can grow either as a result of positive technological changes in agriculture (growth of p_a and increase in u) or as result of limitations of the *capoeira's* capacity (decrease in p_c). These two drivers create a multiplicity of thinkable situations not captured by the categories of IBGE, so that, hypothetically, it's "Unused Lands" category could be covering both productive *capoeiras* and *capoeiras* derived from agricultural systems' ascending trajectories. Therefore, the different means of *capoeiras* should be better understood and balanced before we are able to judge the resulting systems, be it in economic or in ecological sense. Insofar as the environmental goods market becomes true, the more important becomes the task, which will occupy us in the following section.

2.4. Capoeira: function and disfunction

Three types of decisions lead to the *capoeira's* existence:

a) The use of a technique that requires resting time – in this case the *capoeira* is part of the production system.
b) Decisions that lead to the abandonment of areas that are unproductive (productivity tends to zero), the technological procedures are constant and therefore, the *capoeiras* result from technology. We shall underline the broader understanding of technology we hold here, as any procedures that mediate labor and nature conditioned also by intangible institutional apparatus. In this case, technology presupposes the socially determined ownership relations, which allow the continuous discard of land *turned unable* to produce the usual goods.
c) Decisions to use technologies that make the land in operation more productive, reducing the area needed to produce the same output. In this case, the *capoeiras* are results of innovation.

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For the first item above, the *capoeira's* function is forming biomass to be used in agriculture. In this case, the *capoeira* is considered a production tool, as if it was a machine producing nitrogen, phosphorus, and other elements needed in agriculture. For this reason, we will call this *capoeira* "Capital-Capoeira". The resting time in this case is the processing time for the *Capital-Capoeira*. Nature and its laws that govern the ecosystems determine the value of P_c in formula (5). On the other hand, agriculture variables (P_a/P_c, p_a, and u) resultant from the *capoeira's* development as part of economical activities, through the market, determines the resting time. In a way, it constitutes secondary vegetation with duration determined by the logic of its productive process. Giving the "Capoeiras" the time they need, the extension of the *capital-capoeira* is endogenously contained, regulated by the extension of the agricultural needs (refer to (2)), and there is no limitation in repeating the slash-and–burn or eventually slash-and–mulch operations, for in such a context there is no structural limitation in forest regrowth, as in the cases showed by Johnson et alii (2001), Vieira (1996), Uhl (1987) and Uhl and Jordan (1984).

In the second condition, the *capoeira* is a result of the deterioration of the soil-plant-climate relationships of an area, as a resultant of the technological impacts on soil, water, or air. The *capoeiras* will then be treated by the agents as depreciated products, as scrap. We will call these *capoeiras* either *scrap-capoeiras* or *waste-capoeiras*. In this case, as a result of the type of use that create the *capoeiras*, the p_c and P_a can be very small, even tending to zero; therefore, time "n" in formula (5) can be correspondently very high, even tends to infinite, regardless of the other conditions. The extent of "n" is inversely related to decrease in regrowth rates of secondary forest associated to previous land use procedures as those described by Zarin et alii (2005), Fearnside and Guimarães (1996), Buschbacher, Uhl and Serrão (1988), Uhl, Buschbacher, and Serrão (1988) and also by Nepstad, Uhl and Serrão (1991). In these terms, the *capoeiras* would not be endogenously contained. It is important to note however that the *scrap-capoeiras* are not always symptoms of economic failures of the activities that generate them. They can be conditions to maintain and even increase profitability in the view of the private agents. As we will show critically in section 4, this may be a major problem for political measures targeting sustainability.

The third condition is observed when a better technology is used, reducing the amount of land needed to produce the same output, for example, when cultivation of annual and semi-annual cultures or forestry substitute shifting cultivation or extensive ranching (COSTA, 1996[a]

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and 1997). The *capoeira* is the result of use of new techniques that made *capital-capoeira*, as described above, obsolete, that is, without a function within the production system. Even keeping its operational capability the *capital-capoeira* will be seen as an idle asset, constituting stock. We will call this *capoeira* as *reserve-capoeira*. Due to the conditions that form the *reserve-capoeira*, P_a (production that depends on the *capoeiras*) in formula (5) is very small, approaching zero. Therefore, as the above mentioned *scrap-capoeiras*, the *reserve-capoeira* will not be constrained by time to be transformed into agricultural elements. Nevertheless, there is a significant difference between these two kinds of *capoeiras*. For the *scrap-capoeiras*, the fact that p_c tends to zero makes *Pc* (that is, the objective maturity of the *capoeira*) tends to zero as well. This indicates that this kind of *capoeira* can represent degradation of the environment and, ultimately, step to desertification (refer to (3). Conversely, the mechanism that creates *reserve-capoeiras* allow a p_c different from zero, leading along the time to correspondent levels of maturity and complexity and, therefore, creating botanical areas similar to the original biome, the forests.

3. HETEROGENEOUS AGENTS, TECHNOLOGICAL PROCEDURES, AND *CAPOEIRA* FORMATION

The arguments above lead to two questions: what can be said about the proportions of the three types of *capoeiras*? How do they relate to the different production systems (technological, reproductive, and social)? To answer the questions above we need to evaluate how each system relates to the *capoeiras*, how resources are allocated and what are the results of these interactions. Then, it is necessary to analyze in what proportion these relationships apply to each type of *capoeira*.

We consider, just like Arthur (1994b:13-32), that the agents will make path-efficient decisions. That is, they will consider two technologies: T1, which stands in variable *m* (and whose outcome will be *scrap-capoeira*, for example), and T2, which stands in variable $k < m$ (whose outcome will be *reserve-capoeira*, for example). At any instant *t*, T1 will be chosen with payoff $\Pi_{T1}(m)$ if $\Pi_{T1}(m) \geq \text{Max}_j \{\Pi_{T2}(j)\}$ for $k \leq j \leq m$.

The agent's decision is as consistent as the degree of their adherence to the postulate above. This means that, for any agent, the amount of *reserve-capoeira* that is theoretically justifiable is the share of all the types of *capoeiras* he has (his share Ac, as shown in chart 1), which can be

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explained by using a calculation compatible with the path-efficient decision. Even though the decision was made before hand, the results are reflected in the year when the Census took place, favoring activities and procedures that generate *reserve-capoeira*. The same happens with *scrap-capoeira* or *capital-capoeira*.

3.1. The type of capoeiras and the systems associated to them – 1995-96 Census

This logic will allow us to calculate all form of *capoeiras* discussed herein. We will start by discussing the *reserve-capoeiras*. There are those originated from the transition between extensive agricultural systems to intensive agricultural systems and those originated from extensive cattle ranching activities to intensive cattle ranching activities. For the first group, lets consider that areas used for temporary cultures or ranching activities in a sub-area A are converted into areas for permanent cultures or silviculture in a sub-area A_a^p and into *capoeiras* in another sub-area A_c^R , so that

$$A = A_c^R + A_a^P \tag{9}$$

Considering the path-efficient condition to one agent, within a context of constant income, the conversion will happen while

$$A \bullet p \le A_a^P \bullet p_a^P + A_c^R \bullet p_c^r \tag{10}$$

That is, the total area used in its prior function, multiplied by its profitability by unit of area (*p* = proxy of payoff of shifting cultivation), is less or equal to the yield of the area with permanent culture, multiplied by its profitability by unit of area (p_a^P = proxy of payoff of systems with permanent culture), plus the area with *capoeira* multiplied by the profitability of capoeira (p_c^r). Substituting A in (10) for its value in (9), considering further that the *capoeira* value is instantly irrelevant ($p_c^r = 0$) and that the process will convert until the limit, when both sides of the equation are equal, then:

$$\frac{A_c^R + A_a^P}{A_a^P} = \frac{p_a^P}{p} \quad \therefore \quad \frac{A_c^R}{A_a^P} + 1 = \frac{p_a^P}{p}$$

And then,

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$$A_c^R = \left(\frac{p_a^P}{p} - 1 \right) \bullet A_a^P \quad (11)$$

We have the values for this variable in the database created with basis on the agricultural Census, so we can find the area of *reserve-capoeira* for each case explained in 3.2. The caveat though, is that we cannot differentiate extensive cattle ranching from intensive cattle ranching. Therefore, we cannot specify formula (9) and we will not know the amount of *reserve capoeira* originated from the intensification of cattle ranching activities.

The *scrap-capoeiras* (A_c^s) have also two components: the first derives from cattle ranching and the second from shifting cultivation. Those that derive from cattle ranching are determined by the amount of land required for stock breeding activities (A_a^{Pec}) in the set of activities that generate *capoeiras* – ranching (A_a^{Pec}) and temporary cultures (A_a^{Temp}). This proportion is projected to areas with *capoeiras* that cannot be explained by the origination of *reserve-capoeiras* (A_c-A_c^R). Then,

$$A_c^S = \left(\frac{A_a^{Pec}}{A_a^{Pec} + A_a^{Temp}} \right) \bullet \left(A_C - A_C^R \right) \quad (12)$$

Based on the Census data, we can easily calculate the areas for each case. However, we will not be able to calculate the *scrap-capoeira* generated by shifting cultivation.
Finally, we can obtain the *capital-capoeiras* (A_c^K) as the difference shown below:

$$A_c^K = A_C - A_C^R - A_C^S \quad (13)$$

When we apply each of the relations above to the Census data, we will create new variables representing the three types of *capoeiras* in association with other variables defined by the technological systems and social forms of production. The results for the Northern Region are in table 2 below.

Table 2 – Several types of "capoeiras" in the Northern region in technical and production context, 1995-96 (Ha)

Social production basis	Technical condition 1: Based on temporary cultures (F^T)	Technical condition 2: Intensification of permanent cultures (F^P)	Technical condition 3: Predominant Ranching (F^{Pec})	Technical condition 4: Forests (A^{Mata})	Total of land/ utilized[3] E

	Areas with Temporary cultures	Capital-Capoeira (A_c^K)[3]	Areas with permanent cultures	Reserve-Capoeira (A_c^r)[1]	Area for ranching (A_a^{Pec})	Scrap-capoeira (A_c^S)[2]		
1. Peasants	891.507	613.777	542.594	895.443	3.942.476	618.731	9.311.140	16.815.667
2. Corporative	352.704	157.785	185.252	547.757	10.820.183	1.662.800	16.191.153	29.917.633
Northern Region	1.244.211	771.562	727.845	1.443.200	14.762.658	2.281.531	25.502.292	46.733.300

Source: IBGE – Agricultural Census: All states of the Northern Region, 1995-96. Tabulated by the author. Note: [1] – Using relationship (11) with the following restrictions: a) if $A_c^r > Ac$ then $A_c^r = Ac$; b) if $A_c^r < 0$ than $A_c^r = 0$; c) considering p as total net income per unit of area applied to ranching and to temporary cultures, including *capoeiras* for a resting time of six years and utilization of white cultures in the same area for two years. [2] – Using relationship (12) with the following restrictions: $A_c^S > (Ac - A_c^r)$ then $A_c^S = Ac - A_c^r$. [3] – Using relationship (13). [4] – all lands classified as used in the Census. The total of properties that includes swamps and other unusable lands is different..

The *reserve-capoeiras* lands that are associated with 0.73 million ha of areas of permanent cultures, grow to 1.4 million ha, of which 0.9 million correspond to peasants establishments (64% of total) and the remaining 0.5 million (36%) to corporative establishment.

The lands that are in fact abandoned, probably useless, herein treated as *scrap-capoeiras* or *waste-capoeiras*, would be equivalent to 2.3 million of ha, associated with 14.8 million ha of pasture. From these, 30% are associated with peasant production system and 70% with corporative production systems.

The *capital-capoeiras* that are active components of the production systems based on 1.2 million ha of temporary cultures are 771,562 ha of which 80% are from peasant production and 20% from corporative production.

4. DIGRESSION ON ERRORS I: WHAT MEANS UNDERESTIMATIONS?

There are three reasons why the estimations above are underestimated: first, we cannot calculate the effects of the intensification of ranching activities – only the effects of agriculture and silviculture intensification. Therefore, the value of the *reserve-capoeira* is lower than it should be considering intensification of ranching activities. Secondly, we cannot calculate the formation of *scrap-capoeiras* that originate from shifting-cultivation; again, the value of *scrap-capoeira* is lower than the actual. Thirdly, the values of the underestimations presented above correspond to overestimations of the values of *capital-capoeira* that is impossible to demonstrate.

What mean these errors? The immediate answer is that the importance of these errors is bigger when the intensification of ranching and reduction of rotation of *capoeiras* in shifting-cultivation is more relevant. On this topic, we have to consider the following:

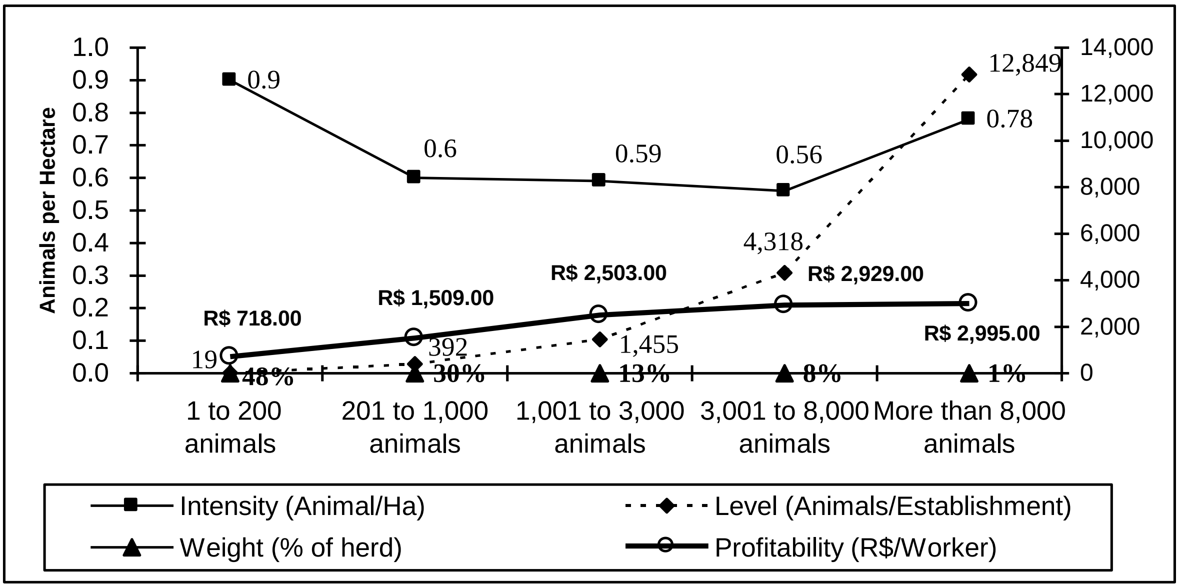
4.1. About the intensification of ranching and importance of error in the reserve-capoeira

Chart 2 shows that, first, cattle ranching does not intensify production if it has less than 4.3 thousand animals. Only beyond that point, on a scale of 12.5 thousand, we can observe intensification. Secondly, the segment that is intensified within this scale represents only 1% of the activity.

In 1995, 48% of the herd originated from establishments with herds of up to 200 animals and average of 19 animals. This group of establishments manages cattle ranching as part of complex and diversified systems, dominantly managed by peasants. These workers are not specialized and stockbreeding represents only 24% of the total production. In addition, 76% of this amount comes from dairy products. These characteristics indicate that these establishments have an intensification rate measured by capacity of 0.9 animal/ha – the highest of all classes of cattle ranching (refer to Chart 2).

For the next four categories – 201 to 1,000 animals, in average 392 animals; 1,001 to 3,000, in average 1,455 animals; 3,001 to 8,000, in average 4,318 animals; and over 8,000 animals with an average of 12,849 animals – the level of specialization increases, representing 80%, 89%, 94%, and 97% of total production of the establishments. The level of intensification of the establishments falls to 0.6 animals/ha and is almost constant in the next two categories – 0.59 and 0.56 animals/ha. It is only in establishments with herds greater than 8,000 animals, that this parameter will increase significantly to 0.78 animals/ha (chart 5).

Chart 2 – Proportion (%) of cattle ranching associated to an average use (animals per establishment) and intensification (animal/Ha) in the Northern region – 1995



Source: Agricultural Census, All States of North Region, 1995-96. Tabulated by the author.

The profitability grows with the level of production, even though at decreasing rates: it jumps from R$1,509 to 2,503 from the first to the second levels of production; from the second to the third it grows to R$2,929 and for the last level it is R$2,995. For all ranching activities, profitability positively correlates to the level of production but it is indifferent to the intensity of land use. Therefore, the error in the formation of *reserve-capoeira* is irrelevant.

4.2. About the formation of scrap-capoeira in shifting cultivation

It seems impossible to use the Census data for evaluating the necessary period for *capoeira* rotation associated with *capoeiras* originated from shifting-cultivation and, therefore, for evaluating how they determine *scrap-capoeira*. However, we can evaluate the amount of *scrap-capoeira* originated from cattle ranching. That is, the resting agriculture is the first step in a trajectory that bifurcates into two systems: one of permanent culture that can be associated with production of dairy products[7] and one of cattle ranching. Many analysts call this trajectory "Capoeira Crisis."

The formation of *scrap-capoeiras* resulting from ranching activities was captured in our estimate, therefore the error associated to this underestimation is irrelevant.

[7] For further details on "capoeira crisis", see Hurtienne (2001). See also Costa (2006) for a extensive analysis of technological trajectories of rural sector in the Amazon.

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5. FORMATION OF *CAPOEIRAS* THROUGH THE EXPANSION OF THEIR BASES: EVOLUTION OF LAND USE IN THE MAIN PRODUCTION SYSTEMS.

Given the 1995 stocks of all types of *capoeiras* and given their technical and social bases, we modeled the evolution of this set of conditions before and after this point. For that purpose, we considered the following:

a. The technical coefficients of the relations among all types of *capoeiras* and their bases are constant. This implies that technology is constant. We will discuss the implications of this assumption later.
b. IBGE's estimates for the evolution of planted areas with permanent and temporary cultures and the expansion of cattle ranching for the Northern region are robust indexes for the evolution of the bases for the rise of "capoeiras".

Thus:

$$F^{T}_{(t)} = A^{T}_{a(t)} + A^{C}_{c(t)} = A^{T}_{a(1995)}.I_{T}.\left(1+\frac{A^{C}_{c(1995)}}{A^{T}_{a(1995)}}\right) \tag{14}$$

$$F^{P}_{(t)} = A^{P}_{a(t)} + A^{R}_{c(t)} = A^{P}_{a(1995)}.I_{P}.\left(1+\frac{A^{R}_{c(1995)}}{A^{P}_{a(1995)}}\right) \tag{15}$$

and

$$F^{Pec}_{(t)} = A^{Pec}_{a(t)} + A^{S}_{c(t)} = A^{Pec}_{a(1995)}.I_{Pec}.\left(1+\frac{A^{S}_{c(1995)}}{A^{Pec}_{a(1995)}}\right) \tag{16}$$

F is the dominant productive basis, *I* the index of the dominant basis – notation (T) meaning temporary cultures, (P) permanent cultures, and (Pec) cattle ranching - expressed as indexes for any year (t) between 1989 and 2005 (refer to table 3).

Table 3 – Evolution of an area planted with temporary cultures[1], permanent cultures[2], and used for cattle ranching[3] in the Northern Region as indexes of agrarian economy 1989-2005 (Indices for 1995 = 1)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Temporary (I_T)	0,76	0,76	0,77	0,90	0,88	0,99	1,00	0,89	0,90	0,97	1,05	1,04	0,92	0,91	1,01	1,13	1,26
Permanent (I_P)	1,00	0,97	0,94	1,01	0,99	0,99	1,00	0,90	0,86	0,88	1,04	1,13	1,17	1,14	1,21	1,12	1,14
Ranching (I_{Pec})	0,60	0,69	0,80	0,83	0,89	0,94	1,00	0,94	1,01	1,10	1,17	1,28	1,42	1,59	1,77	2,07	2,16

Source: IBGE, Municipal Agricultural Production (PAM) e Municipal Ranching Survey (PPM). 1 – Pineapple, Cotton, Peanuts, Rice, Sweet-potato, Sugar Cane, Beans, Tobacco, Jute, Mallow, Cassava, Watermelon, Melon, Corn, Soybeans, Sorghum, and Tomato. 2 – Avocado, Banana, Rubber, Cacao, Coffee, Cashew nut, Baia's coconut, Dendê, Guava, Guarana, Orange, Lime, Papaya, Mango, Passion Fruit, Palm, Black Pepper, Tangerine, Urucum, Grape. 3 – Total number of cattle.

Assuming that all agrarian development was based on the same structure of ownership – that is, all areas appropriated in 1995 were already part of the assets of the agents since beginning of the 90's, and continued being the patrimony on which they operated until 2005 - making *E* a constant, we have:

$$A_{(t)}^{Mata} = E_{(1995)} - F_{(t)}^{T} - F_{(t)}^{P} - F_{(t)}^{Pec} \tag{17}$$

With this, we reconstruct the evolution of the principal elements of used areas, as presented in Table 4

5.1. *Production System and CO_2 Sequestration*

We apply the parameters of emission and carbon sequestration based on Fearnside (2000) and Nepstedt *et al* (1999), as follows[8]:

$$F_{(t)}^{T+} = \overbrace{C.\left(A_{a(t)}^{T} - A_{a(t-1)}^{T}\right)}^{A_{a(t)}^{T+}} + \overbrace{5 \cdot \frac{C}{15} \cdot \frac{A_{c(t)}^{C}}{5}}^{A_{c(t)}^{T+}} \tag{18}$$

$$F_{(t)}^{T-} = -\left(\overbrace{9.A_{a(t)}^{T}}^{A_{a(t)}^{T-}} + \overbrace{\frac{C}{15} \cdot \frac{A_{c(t)}^{C}}{5}}^{A_{c(t)}^{C-}} \right) \tag{19}$$

$$F_{(t)}^{P+} = A_{a(t)}^{P+} + 0 \tag{20}$$

[8] We used these works because they represent the state-of-the-art knowledge in this region. Fearnside (2000), a famous researcher on forestal ecology in the Amazon, has been accounting for important variables in the environmental matters in the Amazon. He updated his 1997 work and presents detailed data for shifting cultivation, original forest, etc. Nepstedt is also a renowned specialist in forestal ecology in the Amazon. His work is less technical, but both his evaluation and choice of parameters seems to me as qualified corroboration of sources. We are aware about the risks of using average values to represent such a large region. However, the methodology presented and the strategic discussion of results reveal to be more important here than the margin of error inherent to these calculations.

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$$F_{(t)}^{P-} = -\left(\overbrace{\frac{C}{20} \cdot A_{a(t)}^{P}}^{A_{a(t)}^{P-}} + \overbrace{\frac{C}{15} \cdot A_{c(t)}^{R}}^{A_{c(t)}^{R-}} \right) \qquad (21)$$

$$F_{(t)}^{Pec+} = A_{a(t)}^{Pec+} = \left(A_{a(t)}^{Pec} - A_{a(t-1)}^{Pec} \right) C + 6.A_{a(t)}^{Pec} \qquad (22)$$

$$F_{(t)}^{Pec-} = \overbrace{6.A_{a(t)}^{Pec}}^{A_{a(t)}^{Pec-}} + \overbrace{\frac{C}{60} \cdot A_{c(t)}^{S}}^{A_{c(t)}^{S-}} \qquad (23)$$

$$F_{(t)}^{Mata-} = A_{(t)}^{Mata-} = 0{,}45.A_{(t)}^{Mata} \qquad (24)$$

$$E_{(t)}^{+-} = F_{(t)}^{T+} + F_{(t)}^{T-} + F_{(t)}^{P+} + F_{(t)}^{P-} + F_{(t)}^{Pec+} + F_{(t)}^{Pec-} + F_{(t)}^{Mata-} \qquad (25)$$

In equations (18) to (25), *C* represents the average stock of carbon in one hectare of the Amazon forest (200 *t/ha*, according to the sources here represented), *F* is the net balance of emission/sequestration of carbon and *E* is the final balance of the sector in each year *t*.

The divisors of C are the number of years required by vegetation of the variable in question to achieve the forest level of carbon reserve. The results will be absorption/release levels in tons of carbon/ha/year. The divisor of *capital capoeira* is the resting time (the results are the volume of *capoeira* that started operating in year *t*). The other parameters [9 in equation (19), 6 in equations (22) and (23), and 0.45 in equation (25)] derive from the two mentioned sources of emission/sequestration in t/ha/year relative to the parametric variable.

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Table 4 – Evolution of the areas used in the agrarian economy of region North by production mode (Ha)i

Form of Production	Year	$A^{T}_{a(t)}$	$A^{T}_{c(t)}$	$A^{P}_{a(t)}$	$A^{R}_{c(t)}$	$A^{Pec}_{a(t)}$	$A^{S}_{c(t)}$	$A^{Mata}_{(t)}$	$E_{(t)}$
Peasants	1990	679.998	468.160	527.644	870.772	2.736.876	429.525	11.102.691	16.815.667
	1991	685.355	471.847	512.259	845.382	3.157.129	495.479	10.648.215	16.815.667
	1992	801.774	551.998	549.313	906.532	3.256.751	511.114	10.238.185	16.815.667
	1993	782.174	538.505	535.927	884.441	3.507.538	550.472	10.016.611	16.815.667
	1994	878.157	604.586	534.570	882.202	3.692.365	579.479	9.644.309	16.815.667
	1995	891.507	613.777	542.594	895.443	3.942.476	618.731	9.311.140	16.815.667
	1996	797.203	548.852	487.152	803.948	3.695.749	580.010	9.902.753	16.815.667
	1997	803.469	553.165	466.189	769.353	3.966.052	622.431	9.635.008	16.815.667
	1998	862.426	593.756	479.831	791.866	4.336.161	680.516	9.071.111	16.815.667
	1999	936.689	644.884	564.791	932.076	4.609.941	723.483	8.403.802	16.815.667
	2000	927.364	638.464	615.098	1.015.097	5.038.817	790.790	7.790.036	16.815.667
	2001	823.071	566.661	633.925	1.046.167	5.607.403	880.024	7.258.415	16.815.667
	2002	809.599	557.386	619.752	1.022.777	6.253.677	981.450	6.571.027	16.815.667
	2003	896.498	617.213	654.746	1.080.529	6.973.150	1.094.364	5.499.165	16.815.667
	2004	1.010.994	696.040	609.105	1.005.206	8.176.983	1.283.293	4.034.045	16.815.667
	2005	1.124.517	774.198	618.714	1.021.065	8.526.747	1.338.185	3.412.241	16.815.667
Corporative	1990	269.025	120.351	180.148	532.665	7.511.398	1.154.320	20.149.726	29.917.633
	1991	271.145	121.299	174.895	517.134	8.664.788	1.331.568	18.836.804	29.917.633
	1992	317.203	141.903	187.546	554.540	8.938.202	1.373.585	18.404.653	29.917.633
	1993	309.449	138.435	182.976	541.027	9.626.489	1.479.358	17.639.900	29.917.633
	1994	347.422	155.422	182.512	539.657	10.133.750	1.557.312	17.001.557	29.917.633
	1995	352.704	157.785	185.252	547.757	10.820.183	1.662.800	16.191.153	29.917.633
	1996	315.395	141.094	166.323	491.788	10.143.037	1.558.739	17.101.256	29.917.633
	1997	317.874	142.203	159.166	470.625	10.884.888	1.672.744	16.270.133	29.917.633
	1998	341.199	152.638	163.823	484.397	11.900.657	1.828.843	15.046.075	29.917.633
	1999	370.579	165.782	192.830	570.166	12.652.052	1.944.314	14.021.910	29.917.633
	2000	366.890	164.131	210.006	620.951	13.829.107	2.125.199	12.601.348	29.917.633
	2001	325.629	145.673	216.434	639.957	15.389.601	2.365.009	10.835.330	29.917.633
	2002	320.299	143.288	211.595	625.649	17.163.308	2.637.585	8.815.909	29.917.633
	2003	354.679	158.668	223.543	660.977	19.137.914	2.941.034	6.440.819	29.917.633
	2004	399.976	178.933	207.960	614.901	22.441.851	3.448.769	2.625.243	29.917.633
	2005	444.889	199.025	211.241	624.602	23.401.784	3.596.287	1.439.806	29.917.633
Total	1990	949.024	588.510	707.792	1.403.437	10.248.274	1.583.844	31.252.418	46.733.300
	1991	956.499	593.146	687.155	1.362.517	11.821.917	1.827.047	29.485.019	46.733.300
	1992	1.118.977	693.902	736.859	1.461.072	12.194.953	1.884.699	28.642.838	46.733.300
	1993	1.091.623	676.939	718.902	1.425.467	13.134.027	2.029.830	27.656.511	46.733.300
	1994	1.225.579	760.008	717.082	1.421.859	13.826.115	2.136.791	26.645.866	46.733.300
	1995	1.244.211	771.562	727.845	1.443.200	14.762.658	2.281.531	25.502.292	46.733.300
	1996	1.112.598	689.946	653.475	1.295.736	13.838.786	2.138.749	27.004.009	46.733.300
	1997	1.121.342	695.369	625.355	1.239.978	14.850.941	2.295.175	25.905.140	46.733.300
	1998	1.203.625	746.394	643.654	1.276.263	16.236.818	2.509.359	24.117.187	46.733.300
	1999	1.307.268	810.666	757.622	1.502.242	17.261.993	2.667.797	22.425.712	46.733.300
	2000	1.294.254	802.595	825.104	1.636.048	18.867.924	2.915.989	20.391.384	46.733.300
	2001	1.148.700	712.334	850.359	1.686.124	20.997.004	3.245.033	18.093.746	46.733.300
	2002	1.129.898	700.674	831.347	1.648.426	23.416.984	3.619.035	15.386.936	46.733.300
	2003	1.251.177	775.882	878.289	1.741.506	26.111.064	4.035.398	11.939.984	46.733.300

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	2004	1.410.969	874.973	817.065	1.620.108	30.618.835	4.732.062	6.659.288	46.733.300
	2005	1.569.405	973.222	829.955	1.645.667	31.928.532	4.934.473	4.852.046	46.733.300

Source: Table 2 for year 1995; for other years, the author's estimates using the methodology presented in the text.

Table 5 – Evolution of the components of the annual balance of carbon emission in the Northern Region by production modes (t))i

	Year	$A_{a(t)}^{T+}$	$A_{a(t)}^{T-}$	$A_{c(t)}^{C+}$	$A_{a(t)}^{P+}$	$A_{a(t)}^{P-}$	$A_{c(t)}^{R-}$	$A_{a(t)}^{Pec+}$	$A_{a(t)}^{Pec-}$	$A_{c(t)}^{S-}$	$A_{a(t)}^{Mata-}$	$E_{(t)}^{+-}$
Peasants	1990	7.305.010	-6.119.986	-4.993.701	0	-5.276.443	-11.610.294	87.097.808	-16.421.258	-1.431.749	-4.996.211	43.553.175
	1991	7.362.551	-6.168.193	-5.033.036	0	-5.122.594	-11.271.765	100.471.855	-18.942.776	-1.651.597	-4.791.697	54.852.748
	1992	30.643.754	-7.215.963	-5.887.981	0	-5.493.131	-12.087.094	38.867.155	-19.540.507	-1.703.712	-4.607.183	12.975.338
	1993	3.260.161	-7.039.567	-5.744.048	0	-5.359.267	-11.792.540	69.697.814	-21.045.227	-1.834.907	-4.507.475	15.634.944
	1994	27.257.679	-7.903.411	-6.448.916	0	-5.345.701	-11.762.688	58.010.686	-22.154.190	-1.931.596	-4.339.939	25.381.924
	1995	10.853.704	-8.023.562	-6.546.955	0	-5.425.937	-11.939.240	72.176.307	-23.654.854	-2.062.437	-4.190.013	21.187.015
	1996	0	-7.174.827	-5.854.416	0	-4.871.523	-10.719.307	0	-22.174.494	-1.933.366	-4.456.239	-57.184.173
	1997	8.628.677	-7.231.219	-5.900.430	0	-4.661.892	-10.258.035	76.235.126	-23.796.313	-2.074.770	-4.335.753	26.605.391
	1998	19.708.231	-7.761.836	-6.333.395	0	-4.798.310	-10.558.208	97.818.070	-26.016.965	-2.268.386	-4.082.000	55.707.201
	1999	23.451.081	-8.430.204	-6.878.761	0	-5.647.914	-12.427.680	80.773.031	-27.659.647	-2.411.610	-3.781.711	36.986.585
	2000	6.647.863	-8.346.279	-6.810.281	0	-6.150.980	-13.534.627	113.434.789	-30.232.902	-2.635.968	-3.505.516	48.866.097
	2001	0	-7.407.643	-6.044.386	0	-6.339.247	-13.948.889	143.950.182	-33.644.420	-2.933.414	-3.266.287	70.365.897
	2002	4.737.325	-7.286.391	-5.945.448	0	-6.197.517	-13.637.026	162.899.086	-37.522.060	-3.271.501	-2.956.962	90.819.507
	2003	25.609.374	-8.068.485	-6.583.610	0	-6.547.464	-14.407.051	181.416.778	-41.838.901	-3.647.881	-2.474.624	123.458.137
	2004	32.179.594	-9.098.942	-7.424.429	0	-6.091.048	-13.402.753	282.605.514	-49.061.900	-4.277.645	-1.815.320	223.613.071
	2005	33.027.256	-10.120.650	-8.258.108	0	-6.187.142	-13.614.198	119.014.725	-51.160.485	-4.460.618	-1.535.508	56.705.271
Corporative	1990	2.025.182	-2.421.229	-1.283.742	0	-1.801.477	-7.102.205	239.041.218	-45.068.385	-3.847.733	-9.067.377	170.474.252
	1991	2.041.134	-2.440.301	-1.293.854	0	-1.748.951	-6.895.122	275.746.487	-51.988.728	-4.438.560	-8.476.562	200.505.544
	1992	11.103.726	-2.854.826	-1.513.636	0	-1.875.459	-7.393.871	106.671.479	-53.629.211	-4.578.617	-8.282.094	37.647.490
	1993	294.978	-2.785.040	-1.476.635	0	-1.829.755	-7.213.688	191.286.678	-57.758.935	-4.931.194	-7.937.955	107.648.454
	1994	9.666.955	-3.126.799	-1.657.837	0	-1.825.123	-7.195.427	159.211.183	-60.802.502	-5.191.040	-7.650.701	81.428.708
	1995	3.160.127	-3.174.334	-1.683.040	0	-1.852.517	-7.303.427	198.088.939	-64.921.096	-5.542.667	-7.286.019	109.485.967
	1996	0	-2.838.552	-1.505.008	0	-1.663.230	-6.557.174	0	-60.858.225	-5.195.797	-7.695.565	-86.313.551
	1997	2.391.821	-2.860.862	-1.516.836	0	-1.591.658	-6.275.006	209.228.428	-65.309.331	-5.575.812	-7.321.560	121.169.183
	1998	6.700.200	-3.070.788	-1.628.140	0	-1.638.234	-6.458.627	268.463.137	-71.403.945	-6.096.143	-6.770.734	178.096.726
	1999	8.086.517	-3.335.212	-1.768.338	0	-1.928.305	-7.602.213	221.682.773	-75.912.310	-6.481.046	-6.309.860	126.432.007
	2000	1.450.578	-3.302.010	-1.750.734	0	-2.100.061	-8.279.351	311.323.450	-82.974.644	-7.083.996	-5.670.607	201.612.626
	2001	0	-2.930.660	-1.553.843	0	-2.164.339	-8.532.762	395.073.397	-92.337.607	-7.883.363	-4.875.899	274.794.925
	2002	844.502	-2.882.690	-1.528.409	0	-2.115.949	-8.341.990	447.078.945	-102.979.847	-8.791.949	-3.967.159	317.315.453
	2003	8.991.513	-3.192.107	-1.692.463	0	-2.235.428	-8.813.026	497.901.023	-114.827.482	-9.803.446	-2.898.368	363.430.216
	2004	11.445.243	-3.599.783	-1.908.614	0	-2.079.599	-8.198.681	775.615.001	-134.651.108	-11.495.897	-1.181.359	623.945.203
	2005	11.636.213	-4.003.998	-2.122.930	0	-2.112.407	-8.328.026	326.637.668	-140.410.704	-11.987.625	-647.912	168.660.278
Total	1990	9.330.192	-8.541.215	-6.277.443	0	-7.077.920	-18.712.499	326.139.026	-61.489.644	-5.279.482	-14.063.588	214.027.427
	1991	9.403.685	-8.608.493	-6.326.890	0	-6.871.545	-18.166.887	376.218.342	-70.931.505	-6.090.157	-13.268.259	255.358.292
	1992	41.747.480	-10.070.789	-7.401.617	0	-7.368.589	-19.480.965	145.538.634	-73.169.718	-6.282.329	-12.889.277	50.622.828
	1993	3.555.139	-9.824.607	-7.220.684	0	-7.189.022	-19.006.228	260.984.492	-78.804.162	-6.766.101	-12.445.430	123.283.398
	1994	36.924.634	-11.030.210	-8.106.753	0	-7.170.824	-18.958.115	217.221.869	-82.956.693	-7.122.636	-11.990.639	106.810.632
	1995	14.013.831	-11.197.896	-8.229.995	0	-7.278.454	-19.242.667	270.265.246	-88.575.949	-7.605.103	-11.476.032	130.672.982
	1996	0	-10.013.380	-7.359.424	0	-6.534.753	-17.276.481	0	-83.032.718	-7.129.163	-12.151.804	-143.497.724
	1997	11.020.497	-10.092.081	-7.417.266	0	-6.253.550	-16.533.042	285.463.554	-89.105.643	-7.650.583	-11.657.313	147.774.573
	1998	26.408.431	-10.832.624	-7.961.535	0	-6.436.543	-17.016.836	366.281.207	-97.420.910	-8.364.529	-10.852.734	233.803.927

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	1999	31.537.599	-11.765.416	-8.647.099	0	-7.576.219	-20.029.893	302.455.804	-103.571.957	-8.892.656	-10.091.571	163.418.592
	2000	8.098.441	-11.648.289	-8.561.015	0	-8.251.041	-21.813.978	424.758.239	-113.207.546	-9.719.964	-9.176.123	250.478.724
	2001	0	-10.338.303	-7.598.229	0	-8.503.586	-22.481.651	539.023.580	-125.982.027	-10.816.777	-8.142.185	345.160.822
	2002	5.581.827	-10.169.080	-7.473.858	0	-8.313.466	-21.979.016	609.978.031	-140.501.907	-12.063.450	-6.924.121	408.134.960
	2003	34.600.887	-11.260.591	-8.276.073	0	-8.782.892	-23.220.077	679.317.802	-156.666.384	-13.451.327	-5.372.993	486.888.353
	2004	43.624.836	-12.698.725	-9.333.043	0	-8.170.647	-21.601.434	1.058.220.515	-183.713.008	-15.773.541	-2.996.680	847.558.274
	2005	44.663.468	-14.124.648	-10.381.038	0	-8.299.550	-21.942.224	445.652.393	-191.571.189	-16.448.242	-2.183.421	225.365.549

Source: Table 2 for year 1995; for other years, the author’s estimates using the methodology presented in the text.

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The emission balances by year, from 1990 to 2005, and their emission and sequestration components by technical basis and mode of production, as well as the results of applying this method are presented in Table 5. In the next chapter, we will discuss these results in terms of the question initially posed. For now, it is worth recalling that the balance value for 1990, of 214.1 Gt of CO_2 equivalents, is very different from, though not incompatible with Fearnside's balance of 353-359 Gt of CO_2 equivalents. This difference is due to the size of the region described. Our calculation accounts for the Northern Region, while Fearnside's accounts for the Legal Amazon (FEARNSIDE, 2000, p. 2) that includes Mato Grosso and parts of Maranhão State in addition to the seven states of the Northern Region. The other factor that can explain the difference, even though on smaller scale, is that we do not account for logging activities as Fearnside does.

6. DIGRESSION ON ERRORS II: IS IT POSSIBLE TO ASSUME THAT CATTLE RANCHING DID NOT INTENSIFY WITH TIME?

In estimates presented above, we assume that technological parameters are constant. This is a fact mostly accepted for both temporary and permanent cultures in the Northern region. However, we have to discuss whether this assumption is valid for cattle ranching. Margulis' (2003, op. cit.) work shows a tendency to form a "consolidated frontier" in the Amazon, based on professional and profitable cattle ranching activities that exist in this region. Such assertion suggests that cattle ranching activities evolve by intensifying the use of land. Nevertheless, what it shows is that ranching in Amazon is a business activity, in the sense that it is profitable. However, it does not indicate that the use of land is intensified. On the contrary, it seems that extensive use of land is a condition for the profitability of the activity. We demonstrated this in 4.4 for the year of 1995. Based on the above assumptions, let us see what happens in more recent years.

In 2002 and 2003, FNP – Consultants researched annual cost and profitability for cattle ranching activities. The research encompassed several ranches in 7 regions of Legal Amazon – 4 in Mato Grosso, 2 in Pará, 1 in Rondônia, and 2 in Tocantins – distinguishing 3 levels of technological intensity (extensive 0.6 animals/ha; semi-intensive 0.8 animals/ha; intensive 1 animal/ha) and two levels of production 500 and 5.000 animals. It presented two indicators of profitability: pay back expressed as profitability divided by total assets and profitability per unit of area. Chart 4 below shows the average values obtained for Amazon for 2003. Based on this chart, we can reach the following conclusions:

- *Level 500 animals* – The profitability in a more extensive level (0.64 animals/ha) is the highest for the production units with an average of 500 animals.

- *Level 500 animals* – Based on both indicators, as the technology level increases to 0.86 animals/ha, the smaller production units (average of 500 animals) are less efficient reaching negative profitability in a higher technological level (1.02 animals/ha).

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- *Level 5,000 animals - T*he profitability of the lower technological level (0.61 animals/ha) on a larger scale of production *(average of 5.000 animals)* is four times higher than that of a lower scale of production *(average of 5.000 animals)* with the same technological level.
- *Level 5,000 animals* – As the technological level increases the profitability by area also increases. This is true despite the fact that the payback is smaller in the intermediate level of (0.79 animals/ha) – reaching its maximum at the level with highest intensiveness of land use (0.98 animals/ha).

These results, compatible with those of the Census, indicate that the intensification of cattle ranching for the meat market is not path-efficient. It does not produce a consistent trajectory. If the establishments with an average herd of 500 animals switched to a more intensive technology of 0.86 animals/ha their profitability would be reduced in approximately 35%. If they intensified further to 1.02, the profitability would decrease at higher rates. However, for a lower intensity of 0.6 animals/ha, the profitability grows with the level of production. As shown in chart 4, considering point A where the profitability per unit of area is R$ 27.9 for 500 animals and intensity of 0.6 animals/ha; and considering point B where profitability is R$ 92.6, for 5,000 animals, and the same intensity of 0.6 animals/ha. the angular coefficient of a line that goes from A to B would be 0.014. It means that, for every additional 100 animals, the profitability increases R$ 1.40, a 5% increase in profitability.

In summary, cattle ranching activities in the Amazon combine technological solutions with the extensive use of land that generates *scrap-capoeiras*, and the profitability grows with the level of business.

Technological developments in this area are rather focused on the herds than on grassland conditions. The technological advances internalize the institutionalized credit, especially credits from FNO that are vital for the scale of production. From this, increases the tension that lead to the acquisition of new lands.

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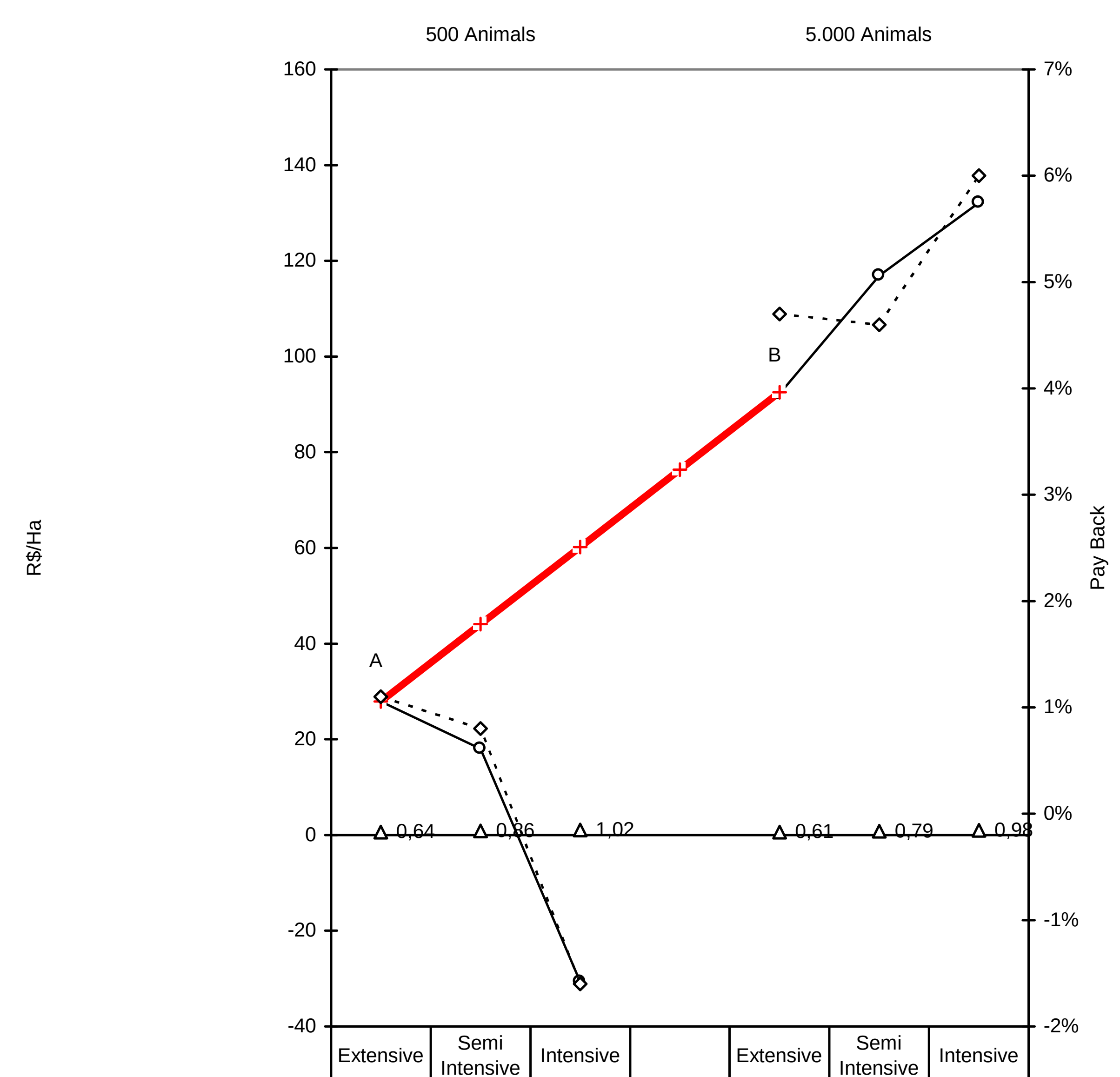
Chart 4 – Pay Backs (%) and profitability per hectare (R$/Ha) for different production and technology levels for the Amazon and the rest of Brazil in 2003



	Extensive	Semi Intensive	Intensive		Extensive	Semi Intensive	Intensive
Animals per Hectare	0,64	0,86	1,02		0,61	0,79	0,98
R$/Ha	27,9	18,0	-30,7		92,2	116,9	132,1
Profitability	27,9	44,05	60,2	76,35	92,5		
Pay Back	1,1%	0,8%	-1,6%		4,7%	4,6%	6,0%

Source: FNP, 2003.

7. DISCUSSION OF RESULTS

The agrarian economy of the Amazon constitutes both a physical and a social system. In other words, a social system that is part of a broader system regulated by physical and natural laws. The social system reproduces itself through entropic processes transforming highly structured forest material in production means, like agricultural and cattle ranching systems, and waste (the CO_2 energy dissipated and the relatively degraded matter of the *scrap-capoeiras*). In the agricultural systems and in the *capoeiras*, the processes of CO_2 absorption are negentropic factors due to their potential ability to neutralize damaging effects of emissions. The emission that is not neutralized is an indicator of produced entropy and, thus, an objective measure of a need for sustainability. This

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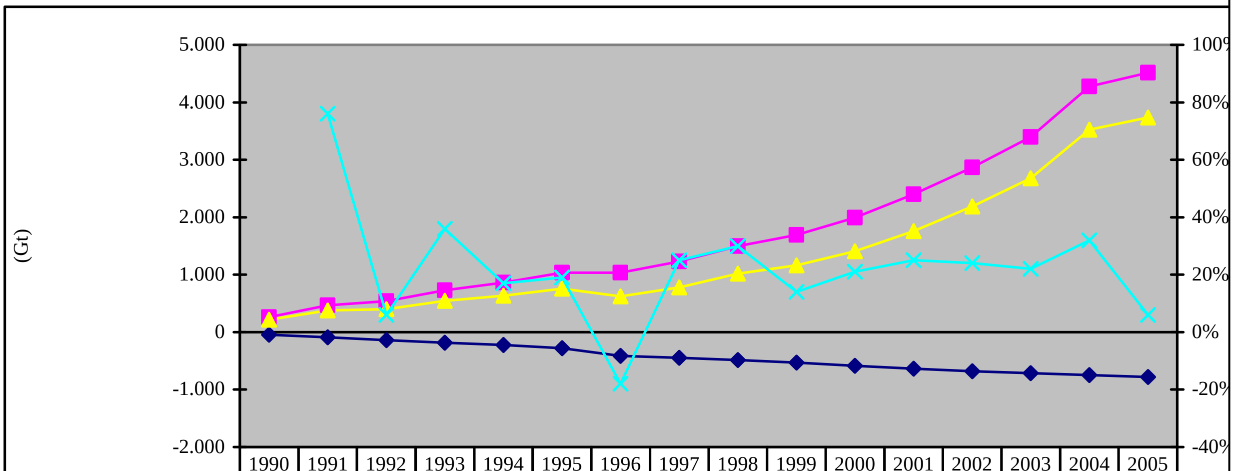
need, that is condition of permanence for a society, is at last resort the foundation of the market for environmental assets.

The net measure of carbon stocked (accumulated annual difference emission-sequestration) from the agrarian economy in the Northern region is an indicator of its contribution to the global entropy. Chart 5 shows the evolution of the order of magnitude and its determinants (on the left axis shows tons of carbon), as well as the growth rate of the net result (right axis in percentage – yearly).

The figures show that the accumulated value increased 10 fold in 15 years, from an average of 330.2 Gt in the first three years to an average of 3,313 GT in the last three years. This result is in itself very impressive and is determined by the emissions vector, which undergoes a rapid growth -, the average of the three first years being multiplied by 9.6 in data for the last three years. However, it is most important to note that some sequestration vectors are evolving spontaneously (also rapidly by factor 8.1) – that is, moved by economic logic. This suggests, for heuristic solutions, strategic ways to explore this subject. We will return to this later.

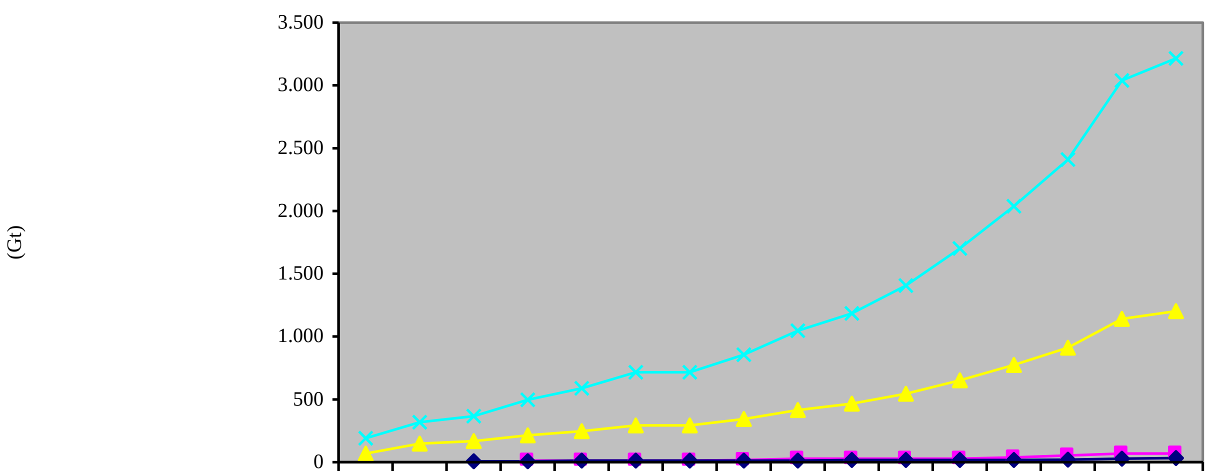
Chart 5 – Evolution of balance of net emission and carbon sequestration of the agrarian economy in the Amazon, 1990 to 2005



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Total Emission	259	468	541	729	861	1.035	1.035	1.229	1.500	1.693	1.995	2.397	2.865	3.394	4.274	4.517
Total Sequestration	-45	-91	-141	-183	-225	-278	-413	-449	-483	-530	-586	-638	-679	-716	-749	-781
Balance	214	377	400	546	636	757	622	780	1.017	1.163	1.409	1.759	2.187	2.678	3.525	3.735
Growth Rate		76%	6%	36%	17%	19%	-18%	25%	30%	14%	21%	25%	24%	22%	32%	6%

Source: Table 5. Notes: 1 – Yearly values were accumulated. 2 – Total emission is the sum of positive values. 3 – Carbon sequestration is the sum of negative values. 4 – Balance is the sum of 2 and 3.. 5 – Yearly growth rate.

Chart 6 – Evolution of carbon emission vectors in the agrarian economy in the Amazon, 1990 a 2005 (accumulated values)



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Peasant Temporary Cultures	-	-	-	13	13	13	13	19	27	27	27	27	38	53	68	68
Corporative Temporary Cultures	-	-	7	7	12	12	12	12	14	17	17	17	17	21	27	32
Pec Peasants	69	149	167	214	247	294	294	344	414	465	545	652	775	911	1.140	1.203
Pec Corporative	190	319	367	496	589	717	717	855	1.046	1.185	1.406	1.701	2.037	2.410	3.039	3.214

Source: Table 5 - See notes in chart 5. 1 – Annual values are accumulated. 2 – For each year, the values with positive sign were added.

When we examine the rate growth, we identify two very well defined phases: for the first phase, the prevailing rates start very high but decrease until approximately 1996. From that point on, the rates start to grow with some indication of decline towards the last years of the series. The variations derived from the conjuncture of the main products suggest an explanation based on the fluctuation of the prices of meat and other commodities expressed in domestic currency. There is also a less noted influence of the public policies of subsidies. Especially those related to the FNO (the Constitutional Credit Fund for the Northern region), observed from differentiated emphasis on these same phases: the first one represented by the orientation towards systems based on permanent cultures practiced by peasants and the second based on the return to ranching activities practiced by corporations and ranchers (COSTA, 2005).

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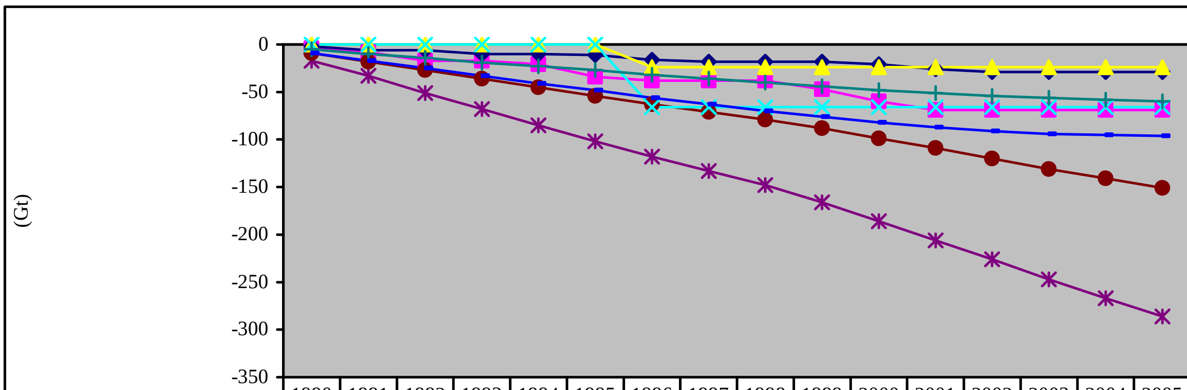
Chart 7 – Evolution of Carbon sequestration vectors in the agrarian economy of the Amazon, 1990 a 2005 (accumulated values)



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
FPeasants Temporary	-4	-8	-17	-17	-21	-34	-38	-38	-38	-47	-60	-69	-69	-69	-69	-69
FCorporative Temporary	-2	-6	-6	-10	-10	-11	-16	-18	-18	-18	-21	-26	-29	-29	-29	-29
Fpeasants Permanent	-17	-33	-51	-68	-85	-102	-118	-133	-148	-166	-186	-206	-226	-247	-267	-286
Fcorporative Permanent	-9	-18	-27	-36	-45	-54	-63	-71	-79	-88	-99	-109	-120	-131	-141	-151
FPeasant Ranching	0	0	0	0	0	0	-24	-24	-24	-24	-24	-24	-24	-24	-24	-24
Fcorporative Ranching	0	0	0	0	0	0	-66	-66	-66	-66	-66	-66	-66	-66	-66	-66
FPeasant Forest	-5	-10	-14	-19	-23	-27	-32	-36	-40	-44	-48	-51	-54	-56	-58	-60

Source: Table 5. Notes: 1 – Yearly values were accumulated. 2 – Total emission is the sum of positive values. 3 – Carbon sequestration is the sum of negative values. 4 – Balance is the sum of 2 and 3. 5 – Yearly growth rate

In addition, there are four points worth highlighting:

1. The weight of the system based on cattle ranching for meat production practiced by corporative establishments that produce *scrap-capoeiras* in the emissions of CO_2 (Chart 6).
2. The weight, also fundamental, of the peasant systems based on permanent cultures that produce *reserve-capoeiras*, for carbon sequestration (Chart 7)
3. The weight of the corporative systems of permanent cultures for carbon sequestration (Chart 7)
4. The decreasing weight of the forest in the definition of the net position (Chart 7)

8. CONCLUSION

The "capoeiras" are part of the rural landscape and have great importance in the Amazon. In 1995, when the last Census was carried out, they accounted for 4.5 million hectares. The way these areas are perceived can significantly influence the inventory of environmental assets related to agricultural land in the Amazon. When discussing economic and ecological sustainability of the agriculture in the Amazonian region, acknowledged authors assume that the "capoeiras", originated from non-used lands, are liabilities. They consider these areas are degraded and as having no function because they are associated with non-sustainable agricultural practices. Thus, this Census' variable would indicate that theses systems are unsustainable. According to the 1995 Census, the Northern Region had 3.4 million hectares of "capoeiras" originated from non-used lands, representing 76% of all "capoeiras" and 6% of appropriated lands.

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Above, we showed that it is possible to explain that 42% of the areas that are classified as "Non-Used Lands" by IBGE are resultant from intensification of the use of land due to the introduction of permanent cultures. Several studies converge to show that this is a phenomenon present in the Amazon as a whole. Studies in areas like the Northeast of Para (COSTA, 2000) in the early 80's, Rondonia (MACIEL, 2004), South and Southwest of Pará (SOLYNO, 2004; MICHELLOTI, 2002), Low and Medium Amazon, and Alto Solimões (COSTA, INHETVIN, 2007) in the 90's and in the current decade show that areas classified as *Reserve-Capoeiras* are result of innovations. These innovations indicate that the agriculture in the Amazon is moving upward, rather than downward towards decadence as once thought.

These findings are very important because they demonstrate the existence of a consistent technological path. This path is a result of evolutionary and adaptive patterns that are efficient when resolving conflicts inherent to shifting-cultivation. For instance, the quest for solutions for crisis of this production pattern - an increasing number of peasant establishments will look for new patterns like fruit culture and industrial commodities of permanent or semi-permanent cultivation. On the other hand, it is a consistent path because it relies on regional urban markets of great importance and rapid growth, as well as on the expansion of national and international markets for regional products. In addition, it relies on the integration with the local processing industry that are diversifying, modernizing, and growing at rapid rates (COSTA, INHETVIN, 2007; COSTA, ANDRADE, FIOCK, 2006; SANTANA, 2004; LOPES, SANTANA, 2005; SANTANA, GOMES, 2005.)[9]

We have to highlight two points when examining the ranches and corporations that justify approximately 1/3 of the *Reserve-Capoeiras*: first, the implementation of permanent cultures by them is more dependent of institutionalized credit resources and, secondly, cultivation of permanent cultures is not very profitable. This can be due to difficulties to have homogeneous plantation of large areas in the Amazon (COSTA, 1993; COSTA, 2005). The intensive agronomic systems, as well as the hot and humid climate are the cause of the main problems with homogeneous plantation of large areas. A number of fungi, bacteria, and invasive plants attack the plantations limiting their development. These limiting factors reduce cultures life cycle, the capital utilization and production output; therefore, the production cost goes up, sometimes turning agriculture production unfeasible. Another factor that limits the extensive agricultural production is the intense rainfall. The high pluviometric indices of the region promote leaching of both natural nutrients and fertilizers, leading to poor soils. All these limitations foster cattle ranching activities in the Amazon that is as profitable as the market allows to, and in the proportion of its ability to generate *scrap-capoeiras*.

Regarding the carbon balance, CO_2 emission, the main vector of entropy, is principally linked to the dynamic that produces *scrap-capoeiras* associated with cattle ranching: in total, between the early 90's until now, carbon emission in the rural Amazon (based on the relation established in 1995) increased 9.6 times, reaching 3,313 Gt. On the other hand, the carbon sequestration by the dynamics that produce *reserve-capoeiras* associated with permanent cultures

[9] Oils, cosmetic, etc...

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and forest (main vector in the capacity to sequestrate CO_2 and to support negentropic processes in the rural sector of Amazon) grew at similar pace to -749 Gt. It becomes clear the enormous and increasing absolute gap in favor of entropy by net emission of the former trajectories. On the other hand, it also comes out that, although responsible for just a fraction of the emission, the capacity of carbon sequestration by the later trajectories is increasing at a similar pace.

Therefore, a broad policy to reduce the net emission balance should take into account both courses of action. Primarily, it has to tackle with the foundation of the main emission vectors – cattle ranching in the top –, assembling institutional resources to contain them. In this regard, the article presents some evidence that the activity is vulnerable because the payoff is easily contestable, representing low opportunity costs. However, we have also to consider the possibilities of the systems that promote carbon sequestration, as forestry and agricultural systems based on perennial crops. Forestry could replace still existing or evolving *scrap-capoeira* of the big ranching farms; in its turn, perennial diverse crops systems, replacing shifting cultivations of the familiar farms (peasants) withdraw land from the *capital-capoeira* function, letting them free, as *reserve-capoeira*, to be even diversified forest again. There are current trajectories showing endogenous ability in this perspective. All this, however, will depend on some factors including the development of the environmental goods market.

In this regard, the balances produced contribute to calculate virtual social gains and losses (for the country and region) associated with a possible worldwide carbon market. To illustrate, from 1990 to 2005, accumulated carbon emissions was 4,517 Gt; in a market with purchase power[10] of US$ 1.00/t, it would be equivalent to a loss of US$ 4.5 billions. In addition, if we assume that the purchase power of the market increases the carbon price to US$ 10.00, the loss would be US$ 45 billion. The tradeoffs of these alternatives are the cost of social opportunity associated with the minimization of this loss – leading to reflect on the institutional conditions and needs that could turn it less limiting towards an ideal of sustainability.

[10] This purchase power is a determinant of the price of the environmental assets but it is determined by non-economical decisions – politics and ethics. The following comment from Herman Daly about formation of prices of environmental assets is very informative: “A distinction should be made between ‘price-determined’ and ‘price-determining’ decisions. The criteria underlying the collective setting of the aggregate constraints are ecological and ethical. These ecological and ethical decisions are price-determining, not ‘price-determined’. (DALY, 1999:98).

REFERENCES

ALTVATER, E. *Sachzwang Weltmarkt. Hamburg.* VSA-Verlag, 1987.

ALTVATER, E. Ilhas de Sintropia e Exportação de Entropia - Custos Globais do Fordismo Fossilístico. *Novos Cadernos NAEA* (11): 3-56, nov. 1993.

ARTHUR, W. B. Path Dependence, Self-Reinforcement, and Human Learning. In: ARTHUR, W. B. *Increasing Returns and Path Dependence in the Economy*. Michigan, The University of Michigan Press. Pp.134-158, 1994a.

ARTHUR, W. B. Competing Technologies. Increasing Returns, and Lock-In by Historical Small.. Events. In: ARTHUR, W. B. *Increasing Returns and Path Dependence in the Economy*. Michigan, The University of Michigan Press. p. 13-32. 1994b.

BRIENZA JUNIOR, S, VIEIRA, I C G, VIEIRA, I. C. G.; YARED, J. Considerações sobre a Recuperação de Áreas Alteradas por Atividades Agropecuária e Florestal na Amazônia Brasileira. *Boletim de pesquisa* EMBRAPA/CPATU, v. 83, p. 1-27, 1995.

BUSHBACHER, R., UHL, C., SERRÃO, E.A. Abandoned pasture in eastern Amazonia II. Nutrient stocks in the soil and vegetation. *J. ecol.* 76: 682-699, 1988.

BUNKER, S.G. *Underdeveloping the Amazon: Extraction, Unequal Exchange, and the Failure of the Modern State*. Chicago, University of Chicago Press, 1985.

CHAYANOV, A. *Die Lehre von der bäuerlichen Wirtschaft: Versuch einer Theorie der Familienwirtschaft im Landbau*. Berlin, Verlag Paul Parey, 1923.

CHOMITZ, K. e THOMAS, T.S. *Geographic Patterns of Land Use and Land Intensity*. World Bank, Development Research Group, Draft Paper, Washington, D.C., 2000.

COSTA, F. A. *Pesquisa Agropecuária na Amazônia e os Fundamentos do Desenvolvimento Rural*. Brasília, CGEE (Relatório de Pesquisa), 2006.

COSTA, F. A. Questão Agrária e Macropolíticas para a Amazônia. *Estudos Avançados*, V.19, N. 53, jan.-abr. 2005:131-156, 2005.

COSTA, F. A. *A Formação Agropecuária da Amazônia*. Belém, NAEA, 2000a.

COSTA, F. A. O Investimento Camponês: Considerações Teóricas. *Revista de Economia Política*. Nobel, São Paulo, v.15, n.1, p.83 - 100, 1995.

COSTA, F. A. Agricultura Familiar em Transformação na Amazônia: o caso de Capitão Poço e suas implicações para a política e o planejamento agrícola regional. *Revista Econômica do Nordeste*, v. 27, n.4, pp. 633-672, 1996a.

COSTA, F. A. Padrões de Reprodução e Dinâmica de Mudança de Camponeses na Amazônia: Os Casos de Capitão Poço e Irituia. *Revista Econômica do Nordeste*, v.28, n.3, p.27 - 43, 1997.

COSTA, F. A. A Relação dos Preços na Agricultura dos Estados Unidos: Uma observação a partir de abordagem baseada em eficiência reprodutiva. *EconomiA*, v.8, n.1. , 2002.

COSTA, F.A. *Grande Capital e Agricultura na Amazônia*: O projeto Ford no Tapajós. Belém, Ed. da UFPa, 1993.

COSTA, F. A. e INHETVIN, T. *A agropecuária na economia de várzea da Amazônia: os desafios do desenvolvimento sustentável*. Manaus, IBAMA/PROVÁRZEA (in print), 2007.

COSTA, F. A., ANDRADE, W. FIOCK. O arranjo produtivo de frutas na região polarizada por Belém do Pará. In: CASSIOLATO, J. E., LASTRES, H. M. Arranjos Produtivos Locais: Novas Políticas para o Desenvolvimento. Rio de Janeiro, E-Papers, 2008.

ISSN 15169111

DALY, H. *Ecological Economics and the Ecology of Economics*. Cheltenham, UK, Edward Elgar, 1999.

DAVIDSON, E.A., CARVALHO, C.J.R., VIEIRA, I. C. G. Nutrient limitation of biomas growth in a tropical secondary forest: early results of a nitrogen and phosphorus amendment experiment. *Eco. Appl*. 14: 150-163, 2004.

DAVIDSON, E. A. ; CARVALHO, C. J. R.; ISHIDA, F. Y.; NARDOTO, G.; SABÁ, R. T.; HAYASHI, S. N.; LEAL, E. C.; VIEIRA, I. C. G.; MARTINELLI, L. A. Recuperation of nitrogen cycling in Amazonian forests following agricultural abandonment. *Nature*. London, v. 447, p. 995-998, 2007.

DENICH, M. ; VIELHAUER, K. ; KATO, M. S. A. ; BLOCK, A.; KATO, O. R. ; SÁ, T. D. A. ; LÜCKE, W ; VLEK, Paul L G . Mechanized land preparation in forest-based fallow systems: The experience from eastern Amazonia. *Agroforestry Systems, Netherlands*, v. 61, p. 91-2004, 2004.

EBELING, J. *Tropical Deforestation and Climate Change*: twards a international mitigation strategy. MS Dissertation, University of Oxford, 2006.

FEARNSIDE, P.M. Greenhouse gas emissions from land use change in Brazil's Amazon region.o In: LAL, R., KIMBLE, J.M. & STEWART, B.A. (eds). *Global Climate Change and Tropical Ecosystems.* Advances in Soil Science. CRC Press, Boca Raton, Florida, U.S.A, 2000.

FEARNSIDE, P.M., GUIMARÃES, W.M. Carbon uptake by secondary forests in Brazilian Amazonia. *Forest Ecology Management*, 80: 35-46, 1996.

GEORGESCU-ROEGEN, N. La ley de la entropía y el problema económico. In: DALY, H. (org.). *Economía, ecología, ética*. México, Fondo de Cultura Económica, 1989.

GEORGESCU-ROEGEN, N. *The entropy law and the economic process.* Harvard, Harvard University Press, 1971.

GEORGESCU-ROEGEN, N. Feasible Recipes versus Viable Technologies. *Atlantic Economic Journal*, 1983.

GEORGESCU-ROEGEN, N. Coments on the papers by Daly and Stiglitz. In: SMITH, V. KERRY (ed.). *Scarcity and Growth Reconsidered*. Baltimore, John Hopkins Press, 1979.

HURTIENNE, T. P. Agricultura Familiar e Desenvolvimento Rural Sustentável na Amazônia. *Estado e Políticas Públicas na Amazônia: Gestão do Desenvolvimento Regional*. Belém, Cejup, 2001.

JOHNSON, C.M., VIEIRA, I., ZARIN, D.J., FRIZANO, J., JOHNSON, A.H. Carbon and nutrient storage in primary and secondary forests in eastern Amazônia. *Forest Ecology and Management*, 147, p. 245-252, 2001.

KATO, M. S. A.; KATO, O. R.; DENICH, M.; VLEK, P. L. G Fire-free alternatives to slash-and-burn for shifting cultivation in the eastern Amazon region: the role of fertilizers. *Field Crop Research*, Amsterdam, v. 62, p. 225-237, 1999.

KATO, M. S. A.; SÁ, T. D. A.; KATO, O. R.; BRIENZA JUNIOR, S. Tecnologia alternativas para uso na agricultura familiar. *Agir Percepção da Gestão Ambiental*, São Paulo, v. 5, p. 205-208, 2004a.

KATO, O. R.; KATO, M. S. A. ; SÁ, T. D. A.; FIGUEIREDO, R. O. Plantio Direto na Capoeira. *Ciência e Ambiente*, Santa MAria - RS, v. 29, p. 99-111. 2004b.

KRUG, T. O Quadro do Desflorestamento da Amazônia. In: MMA. *Causas e Dinâmica do desmatamento na Amazônia*. Brasília, MMA. Pp. 91-98. 2001.

LEAL, E. V.; VIEIRA, I. C. G.; KATO, M. S. A. Potencial de Regeneração da Capoeira após Preparo de Área com Queima e Sem Queima na Região Bragantina. *Agricultura Familiar* (UFPA), v. 4, p. 371-399, 2004.

ISSN 15169111

LOPES, M. L. B.; SANTANA, A. C. O mercado do fruto do açaizeiro (Euterpe Oleracea Mart) no Estado do Pará: 1980-2001. In: CARVALHO, D. F. (Org.). *Ensaios selecionados sobre a economia da Amazônia nos anos 90*. 1 ed. Belém, Pará: Unama, v. 2, 2005, p. 65-84.

MACIEL, A. C. *Dinâmica do processo de ocupação sócio-econômica de Rondônia: Trajetórias e tendências de um modelo agropecuário na Amazônia*. Belém, Tese de Doutorado PDTU/NAEA/UFPa. 2004.

MARGULIS, S. *Causas do Desmatamento da Amazônia Brasileira*. Brasília, Banco Mundial. 2003.

MARX, K. *Grundrisse der Kritik der Politischen Ôekonomie*: Rohenentwurf. Berlin, Dietz Verlag, 1953.

MICHELOTTI, F. Desafios para a sustentabilidade ecológica integrada a trajetórias de estabilização da agricultura familiar na região de Marabá. *Novos Cadernos NAEA*, v.5, n.1, jun. 2002.

NEPSTAD, D. C., UHL, C., SERRÃO, E.A.S. Recuperation of a degraded Amazonian landscape: forest recovery and agricultural restoration. *Ambio* 20: 248-255. 1991.

PEREIRA, C. A.; VIEIRA, I. C. G. A Importância das Florestas Secundárias e os Impactos de sus Substituição por Plantios Mecanizados de Grão na Amazônia. *Interciência*, Brasil, v. 26, p. 337-341, 2001.

PONTE, M. X., VAN DYNE, D. L. Sistemas Agroindustriais Integrados: uma análise por meio da entropia de informação. *Novos Cadernos NAEA*, V.3, N. 1, Jun. de 2000: 47-62, 2000.

SANTANA, A. C. Análise do desempenho competitivo das agroindústrias de polpa de frutas do estado do Pará. *Revista de Economia e Agronegócio*, Viçosa - MG, v. 2, n. 4, p. 495-523, 2004.

SANTANA, A. C.; GOMES, S. C. Mercado, comercialização e ciclo de vida do mix de produtos do açaí no Estado do Pará. In: CARVALHO, D. F. (Org.). *Ensaios selecionados sobre a economia da Amazônia nos anos 90*. 1 ed. Belém, Pará: Unama, 2005, v. 2, p. 85-115.

SÁ, T. D. A.; KATO, M. S. A.; KATO, O. R. A dominância das capoeiras na paisagem agrícola da Amazônia. *Percepção do Diagnóstico Ambiental*, São Paulo, v. 3, p. 109-113, 2004.

SCHNEIDER, R. R. *Government and the Economy on the Amazon Frontier*. Washington, The World Bank, 1995.

SCHNEIDER, R. R., ARIMA, E., VERÍSSIMO, A., BARRETO, P., SOUZA JR., C. *Amazônia Sustentável: limitantes e oportunidades para o desenvolvimento rural*. Brasília/Belém, Banco Mundial/IMAZON, 2000.

SOLYNO SOBRINHO, S. A. *Constrangimentos Institucionais para o Desenvolvimento Sustentável da Agricultura Familiar em Marabá*. Belém, NAEA. Dissertação de Mestrado PLADES/PDTU/NAEA/UFPa.

STERN, N. *The Economics of Climate Change – The Stern Review Cambridge*, Cambridge University Press, 2007.

TEPICHT, J. *Marxisme et Agriculture*: le paysan polonais. Paris, Librarie Armand Colin, 1973.

UHL, C. JORDAN, C. Succession and nutrient dynamics following cutting and burning in Amazônia. *Ecology* 65 (5), 1475-1490, 1984.

UHL, C. Factors controlling succession following slash-and-burn agriculture in Amazônia. *J. Ecol.* 75, 377-407, 1987.

UHL, C., BUSHBACHER, R., SERRÃO, E.A. Abandoned pasture in eastern Amazonia I. Pattern of plant succession. *J. ecol.* 76: 663-681, 1988.

VIEIRA, I. C. G. *Forest Succession after Shifting Cultivation in Eastern Amazônia*. Ph.D. Thesis, University of Stirling, Scotland, 1996.

VIEIRA, I. C. G.; VIEIRA, I. G.; SALOMÃO, R. P.; NEPSTAD, D. C.; ROMA, J.; ROSA, N. O Renascimento da Floresta no Rastro da Agriculturas. *Ciência Hoje*, Rio de Janeiro, v. 20, n. 119, p. 38-44, 1996.

VIEIRA, I. C. G.; PROCTOR, J. Mechanisms of plant regeneration during succession after shifting cultivation in eastern Amazonia. *Plant Ecology*, v. 192, p. 303-316, 2007.

VIELHAUER, K.; KANASHIRO, M.; SÁ, T. D. A. Fallow Vegetation And Secondary Forest (Capoeira). *The Agric. Landscape Of Ent* - Amaz.: Function And Management. Germany Brazil Coop In Env Res And Tech News Latter, Göttingen, v. Abril, p. 2-3, 1997.

ZARIN, D.J., DAVIDSON, E.A., BRONDIZIO, E., VIEIRA, I., SÁ, T., FELDPAUSH, T. SCHUUR, E.A.G., MESQUITA, R. MORAN, E. DELAMONICA, P., DUCEY, M., HURTT, G.C., DENICH, M. Legacy of fire: slow carbon accumulation in Amazonian forest regroth. *Front. Ecol. Environment,* 3(7): 365-369. 2005.

ZARIN, D. J ; VIEIRA, I. C. G.; DAVIDSON, E. A.; BRONDIZIO, E.; SÁ, T.; FELDPAUSCH, T.; SCHUUR, E. A.; MESQUITA, R.; MORAN, E.; DELAMONICA, P.; DUCEY, M.; HURTT, G. C.; SALIMON, C.; DENICH, M. Legacy of fire slows carbon accumulation in Amazonian forest regrowth. *Frontiers in Ecology and the Environment* (Print), v. 3, n.7, p. 365-369, 2005.

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