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Typology and Characterization of Amazon Colonists: A Case Study Along the Transamazon Highway

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Abstract This study develops criteria for classifying the actor groups shaping frontier development along the Transamazon Highway colonization project in the Brazilian Amazon, as a basis to improve understanding of their specific contributions to environmental degradation and socio-economic development. Based on an analysis of responses to questionnaires by 93 colonists representing different migration trajectories, production systems, socio-economic strategies and deforestation patterns, actor groups could be statistically classified according to their type of production and level of capitalization. A property size threshold discriminating small and largeholders in the study area is presented and compared with previous attempts to establish such a threshold. Largeholders practicing large-scale cattle ranching and smallholders practicing diversified family agriculture were found to be the two predominant colonist types. Smallholder farming practices were found to be more appropriate to the local environmental conditions than those implemented by cattle ranchers.

Keywords Brazilian Amazon · Colonization · Smallholder · Cattle ranching · Deforestation · Cluster analysis

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Introduction

Despite considerable efforts to reduce deforestation in the Brazilian Amazon, destruction of the largest remaining tropical forest continues, accounting for about a fifth of the Brazilian Legal Amazon (INPE 2011), and significantly contributing to global environmental problems such as the loss of biodiversity and the emission of greenhouse gases (Fearnside 1996; Laurance *et al.* 1998). Although deforestation is often seen as an unavoidable outcome of development in the Amazon, the majority of the rural population of the Brazilian Amazon continues to live in precarious conditions, with little improvement in their livelihoods in spite of recent growth of the Brazilian economy (Verner 2004). These problems are particularly visible in the so-called frontier regions, where small-scale settlers, large-scale cattle ranchers, timber enterprises, and agro-industrial companies have occupied large tracts of untitled land. The persistence of the enormous environmental and social problems in these regions indicates that policies have not yet managed effectively to address the needs of the wide array of actors with interests in the regions' resources (Godar *et al.* 2008). This paper argues that one of the reasons for this unsatisfactory situation is a lack of adequate differentiation between the diverse groups of colonists, resulting in the formulation of inappropriate policies driven by unfounded generalizations and poor understanding of actor-specific environmental and socio-economic outcomes.

Although a great deal of research describes the social, economic and environmental effects of settlement projects since the first large-scale settlement programs in the Amazon in the early 1970s (Moran 1981, 1993; Smith 1981; Bunker 1983; Fearnside 1985, 1993; Stewart 1994; Pfaff 1999; Aldrich *et al.* 2006; Lima *et al.* 2006; Perz *et al.* 2006; Guillaumet *et al*. 2009), the specific contribution of the

different types of colonists to deforestation and frontier expansion has not been well differentiated. Property size has been considered as a mere scale factor (D'Antona *et al.* 2006), and thus it was taken for granted that the relationship between property size and deforestation is close to linear. Under this perception smallholders and large-scale cattle ranchers have been held equally responsible for deforestation given the larger number of smallholders in many colonization projects (Brandão and Souza 2006). Furthermore, smallholders were often considered as a nuisance remnant of an old-fashioned, authoritarian development model, accused by many to be the main cause of frontier expansion (Costa 2000a). Only a few authors have challenged these platitudinous views (Browder and Pedlowski 2000; Campos and Nepstad 2006) subsumed under the premises of the invasive forest mobility theory (Walker and Homma 1996). More recent studies have revealed that the wealth of the colonists is a stronger correlate of deforestation, with smallholders showing higher potential to develop diverse and sustainable production systems in consolidated areas (Pacheco 2009). However, the proportionate responsibility for deforestation of smallholders and large-scale cattle ranchers in the Brazilian Amazon remains unclear (Pacheco 2005; Michalski *et al*. 2010; Godar *et al*. 2012). An important reason for these highly variable conclusions is the use of different classification criteria for discriminating among colonists, as discussed below.

There are many examples of how the poor understanding of colonist types, their capacities and potentials, and their environmental and socio-economic impacts may have misled public policies. In particular the long-running legal obligation to preserve 50% of properties as forests (called legal reserve) has proven to be incompatible with the basic needs of smallholders in areas of low soil fertility or deficient marketing conditions (Mahar 1989; Ludewigs *et al*. 2009), while also disregarding the huge environmental impact of continuous patches of cleared land in large properties. In spite of that the law was modified forcing new colonists to respect 80% of the forest, regardless of context factors. Additionally, complex bureaucratic requirements for legal timber harvesting that are too demanding and expensive for smallholders make timber management even less attractive compared to agricultural land uses (Lima *et al*. 2006). Similarly, most credit programs, such as the Constitutional Fund for the North (FNO), were not targeted towards the productive priorities of the predominant smallholder families. According to the Banco da Amazonia, between 1990 and 2007 nearly two thirds of available credit was allocated to cattle ranching in the Transamazon Highway (Godar 2009). In the Brazilian Amazon as a whole more than 90% of the FNO funds were allocated to herd expansion in the same period (Smeraldi and May 2009). Meanwhile the successful cocoa industry in some areas of the Transamazon Highway received comparatively less attention and was developed with comparatively little external support.

In general, most of the governmental initiatives to promote rural development have focused on large-scale activities and failed to consider the much more numerous smallholders practicing small-scale agriculture. The more recent settlement projects rarely consider the minimum requirements of different actors for success, locating poor newcomers in areas of low soil fertility, often with poor access and inadequate infrastructure (Godar 2009). Finally, there are many failed, large-scale initiatives, such as the Superintendency for Development of Amazonia (SUDAM) projects, which generally misunderstood both the ecological and productive conditions of the Transamazon Highway, and also the constraints faced by the different colonist groups (Sauer 2005).

There is an urgent need to challenge the simplistic differentiation between small and largeholders and to establish more specific criteria for the differentiation of smallholders (Arnauld de Sartre and Sebille 2008) as a basis for the design of more effective policies. Smallholders and largeholders are too often considered as mere antagonists (Mertens *et al.* 2002) with clearly different production strategies. In this simplified understanding, few authors attempted to rationalize such differentiation by employing more analytical criteria to distinguish between such actors (Smith *et al.* 1997). However several studies revealed strong interrelationships among colonist types, particularly related to the fact that cattle have become increasingly important for smallholders as well as to largeholders (Walker *et al.* 2000; Margulis 2003; Siegmund-Schultze *et al.* 2007) and that the process of land accumulation is not only a result of competition for land among different actors, but also of synergistic interaction between them (Hecht 1985; Alston *et al.* 2000; Benatti and Araujo 2006).

Based on an analysis of the potential and shortcomings of existing classifications of colonists in the Amazon presented in the next section, by using empirical data from four municipalities along the Transamazon Highway, we discuss a methodology for a more accurate classification as a foundation for defining policies that are in better accord with the needs and environmental outcomes of the different types of colonists. We then present a new typology of colonists resulting from the exemplary application of this methodology in the case study of the Transamazon Highway and describe these colonist types in detail. Finally, we discuss the present findings and their implications for future policies and research.

Bases for a Colonist Classification

Little work has been carried out to establish objective criteria to differentiate between colonist actors and to characterize their livelihood strategies in detail. Studies very often assume

that the initial group of colonists targeted by the government defines the current type of colonists (Scatena *et al.* 1996; Summers *et al.* 2004; Perz 2005), generally leading to broad distinctions between smallholder and largeholder frontiers, often respectively referred to as populist and capitalist frontiers (Pacheco 2005), and therefore to potentially misleading analyses of the impact of a certain type of colonist on a given colonization project (Brandão and Souza 2006). However, most efforts to classify colonist actors have concentrated on property size, while other criteria such as livelihood types, productive strategies and development stages have received much less attention (Table 1).

Generally, the criterion of *property size* is assumed to reflect the level of capitalization which largely determines the productive strategy of a given colonist (D'Antona *et al.* 2006). Remarkably, legal regulations use property sizes to formally distinguish between smallholders and largeholders. However, the definitions are diverse. Thus, the Brazilian Institute for Colonization and Agrarian Reform (INCRA) allocated properties of about 100 ha for smallholder settlers. On the other hand federal law[1] defines a small property as a maximum of four fiscal modules (*modulos fiscais*) equivalent to 280–300 ha depending on the municipality in our study area. Also, there is a general lack of scientific criteria in the establishment of property size thresholds. For the Transamazon Highway, for example, Aldrich *et al.* (2006) suggested an area of 3,000 ha to distinguish between small and largeholders in the Transamazon Highway. In contrast Mattos and Uhl (1994) assigned a more realistic upper limit of 100 ha to define smallholders in Eastern Amazonia, whereas medium landholders hold properties between 500 and 3,600 ha. Walker *et al.* (2000) also defined 100 ha as the upper limit for smallholder plot sizes in different locations of the state of Pará, but considered largeholders as owning areas over 1,000 ha, simply excluding all properties in between. Overall, a threshold of 100 ha is most commonly accepted to differentiate between small and largeholders (Margulis 2003; Pacheco 2005; Siegmund-Schultze *et al.* 2007; Godar *et al*. 2012), probably because the Brazilian Institute of Geography and Statistics (IBGE) uses this value in their periodic agrarian surveys. However, this value dates back to the first settlement programs established in the 1970s, when production assets and socio-economic conditions were very different from those at present, and the process of land accumulation was still incipient. Such a fixed value ignores regional diversity in decisive factors for colonists' land-use decisions and productive success, such as soil fertility, production system, access to markets and availability of capital. Hence, to classify smallholders by the 100 ha criterion may lead to significant shortcomings in analyses and consequent decision making.

[1] Lei no 8.629, 25 February 1993

Classification of colonists according to their *livelihood strategies* is nearly exclusively focused on smallholders (Walker *et al.* 2002; Perz 2005), and very few analyses have considered largeholders (Ferreira, 2001). Fearnside (2008) considered a wider diversity of actors, and classified them according to their livelihood strategies into landless migrants, colonists/small farmers, ranchers, drug traffickers/money launderers, gold miners, labourers/debt slaves, capitalized farmers, land-grabbers and sawmill operators/loggers. Chomitz *et al.* (2006) also used this criterion for a broader classification in subsistence-oriented smallholders, extractivists, and those involved in agribusiness. Both classifications consider actor groups typical for frontier contexts, but largely ignore eventual diversification within these groups with respect to productive strategies and capitalization levels. In the same way, colonists may engage in different land-use practices at different intensities and scales, with implications for the scale of the associated economy (Homma *et al.* 1994), management choices and environmental effects (Walker *et al.* 1995). Therefore, such factors need to be considered in conservation and development policies. Another major drawback of classification according to livelihood types is the difficulty of setting quantitative thresholds, which severely affects its practical relevance.

Classifications according to *productive strategies* normally rely on extensive fieldwork, and have greater relevance in practice. For example, Browder *et al.* (2004) surveyed 240 producers in Rondônia and established three predominant productive strategies for colonists: (1) annual crops, (2) perennial crops, and (3) cattle. In addition, they found different subtypes and levels of diversification representing combinations of these three basic strategies. Some authors suggest further differentiation in accordance with the main products, such as cocoa, cattle, coffee, or manioc (Castellanet *et al.* 1998; Walker *et al.* 2002; Pacheco 2005). While this allows an initial understanding of the farmers' capacities and demands, it lacks information about the performance and potential of the production system because it does not consider financial aspects and level of capital accumulation, including property size. However, as the latter often appears as the principal quantitative parameter applied in distinguishing between smallholders and largeholders, combining productive strategy indicators with property size offers the possibility of a more comprehensive classification.

Development aspects are particularly considered by policymakers. Special attention has been given to classifications based on Chayanovian household life cycle theories, which theorize that colonists pass through stages determined by their demographic profile as it changes over time. In turn, it is assumed that this evolution influences productive strategies and land use allocation (Walker and Homma 1996). This theory has been revisited by many authors in Amazonia to include exogenous productive factors, such as the market

Table 1 Main efforts of actor classification in the Brazilian Amazon

Main studies	Differentiation criteria	Types of actors
Brandão and Souza (2006); Perz (2005); Summers *et al.* (2004); Scatena *et al*. (1996)	Type of frontier/ Targeted initial colonization	Smallholders and largeholders.
Siegmund-Schultze *et al.* (2007); Walker *et al.* (2000); Pacheco (2005); Aldrich *et al.* (2006)	Property size (different thresholds)	Smallholders vs. largeholders
Fearnside (2008); Chomitz *et al.* (2006)	Livelihood strategies	Landless migrants, small farmers, ranchers, gold miners, labourers/ debt slaves, capitalized farmers, land-grabbers and loggers, among others
Browder *et al.* (2004); Castellanet *et al*. (1998); Pacheco (2005); Walker *et al.* (2002); Arima and Uhl (1997); Toniolo and Uhl (1995)	Productive strategies	Annual, perennial, and cattle farmers (among others)
Moran (1981); D'Antona *et al.* (2006)	Development stage/capital accumulation	Generic: capitalized vs. non-capitalized
Summers (2008); Arnauld de Sartre and Sebille (2008)	Migration and colonization itineraries: Property size variation, migration background	Recent vs. old colonists. Agricultural vs. cattle ranching background. Region of origin. Land increase/decrease since initial colonization. Type of land ownership.
Pacheco (2005)	Mixed approach: predominant production, wealth (quartiles) and property size	7 subtypes of annual, diversified, perennial and cattle farmers.

for products, land and labor, to explain the capital accumulation by colonist families over time (Aldrich *et al.* 2006; Perz *et al.* 2006; VanWey *et al.* 2007; Summers 2008). Thus, colonists can easily be classified by surveying demographic indicators (such as age and gender structure, family size), and economic indicators. Although this approach distinguishes in theory between capitalized and small family farms (D'Antona *et al.* 2006), without a broader perspective it fails to offer consistent thresholds concerning key aspects that would allow for a meaningful classification, such as property size (Walker *et al.* 2002). This type of characterization lacks a sound empirical basis due to its underlying one-dimensional theoretical approach. In addition a very poor demographic-deforestation correspondence has been found in the Pan Amazon Basin, while it is much higher between land use-deforestation (Perz *et al*. 2005). This suggests that household life cycle data alone are insufficient in explaining actor specific deforestation.

Classifications based on *migration and colonization itineraries* have received comparatively little attention. In light of the high level of conflict on land tenure in frontier areas (Puppim de Oliveira 2008) colonists have been differentiated into those who have maintained their properties at the initial size, those who have divided their property or lost parts to others, and those who have managed to expand their land area (Browder *et al.* 2008; Summers 2008). Another approach based on family colonization dynamics was proposed by Arnauld de Sartre and Sebille (2008), who considered migration itineraries for classifying smallholders. Such classifications are powerful in describing frontier dynamics and in characterizing colonization strategies, but they require additional parameters to describe production systems and capitalization levels. However, if a precise linkage between itineraries and their behavioral correlates is found it is a promising criterion for classification and characterization.

Considering the limitations and applicability of the five classification approaches described above, there have been surprisingly few attempts to apply a combination of these criteria. For example, Pacheco (2005) combined characteristics of the farming system of each surveyed colonist (obtained through hierarchical clustering) with a wealth index by applying a principal components analysis based on different household assets. However, he adopted a standard property size of 100 ha as the discriminating threshold and thereby simplified the influence of property size in his analysis, again highlighting the need to include property size in any classification. Because of the importance of property size in policy implementation, this parameter can be the basis for the more aggregated analyses needed to explain land use dynamics and land cover changes, especially in conjunction with remote-sensing and GIS tools. Pacheco (2006) demonstrated in the Bolivian Amazon that under different development models driven by public policies, colonists with different property sizes had different deforestation performances. Furthermore, D'Antona *et al.* (2006) showed that property size is strongly positively correlated with indicators of environmental effects. Clearly, the use of property size alone is insufficient to

distinguish between the different groups, but it may provide a strong criterion to distinguish broadly between small and largeholders. In addition, a detailed analysis of household-level productive strategies is needed. For instance, a smallholder cultivating 100 ha of cocoa under shade trees causes very different economic and environmental outcomes than cattle ranching in the same area.

Data and Methods

The above analysis revealed three shortcomings of existing attempts for classifying colonists in the Amazon: *i)* the consideration of an insufficient range of classification parameters (often only one parameter is used), *ii)* the use of primarily subjective criteria with non-quantitative grounding, and *iii)* the use of standardized values widely ignoring existing heterogeneity. A sound system of classification should consider a combination of criteria, and should provide meaningfully defined and regionally adapted quantitative property thresholds. In addition, the approach should be replicable and consistent to enable comparative analysis between regions and over time. Through the application of a set of multivariate statistical methods based on information gathered in a detailed survey that explored household characteristics of a pre-selected range of colonist families, this study elaborates relevant classification parameters and discrete thresholds to statistically cluster colonists and describe their characteristics. As a case study we selected four municipalities along the Transamazon Highway, probably the most paradigmatic example of directed colonization in the Amazon, and the one where historically the political identification between the development of Brazil and that of the Amazon has been most intense (Becker 1990).

The Transamazon Highway Case Study

The four municipalities selected, Medicilândia, Brasil Novo, Anapú and Pacajá (Fig. 1), represent the full range of development dynamics along the highway. The vegetation of the area is characterized by diverse formations of Amazonian upland forests. Although the municipalities present differences in local soil and climatic conditions, in general they share broadly similar potential for human settlement. The colonization of this region started in the mid-twentieth century, but since the 1960s, the military governments expanded these efforts on a large scale under the slogan: "*Land without men for men without land*" (Schmink 1982). In 1970 they launched the Program for National Integration (PIN), a mega-project that aimed to alleviate the recurrent poverty in the Northeast of Brazil by easing demographic pressure, to access considerable mining, agricultural and timber resources, and to assure sovereignty over the Amazon, since it represented half the area of the country but contained barely 4% of the population. The project intended to settle one million families by 1980 along a 3,300 km long

Fig. 1 Location of the State of Pará and map of the Transamazon Highway. The Transamazon Highway municipalities are represented in *orange*. The *red circles* indicate the positions of the four studied municipalities

road to be constructed, the Transamazon Highway (BR-230) (Smith 1981). In a sequence of so-called Integrated Colonization Projects (PIC), each family was to receive a property of 100 ha (400 m×2,500 m) along a system of roads arranged in a fishbone pattern. The PICs were planned in a very rational fashion, and included the construction of secondary service roads, social and agricultural infrastructure, technical assistance, the design of the new houses, and agricultural credit (Moran 1981). The original plans were drastically reduced once the difficulties of such a gigantic project became apparent. Finally, the entire program focused on only three PICs along a 20 km wide stretch between the cities of Araguaia, Altamira and Itaituba. After almost a decade only 8,000 families were legally settled, in addition to some 1,600 families that arrived independently in the region (Smith 1981). Today the population is around 300,000.

Although the Transamazon Highway was initially planned to be predominantly oriented towards family agriculture, after the early difficulties the government shifted its focus to favor large-scale ranchers and agribusiness (Martins 1984) since small farmers were viewed as lacking the skills to develop the region. The initial scheme of 100 ha plots was adjusted to accommodate more capitalized immigrants. Bigger properties (*glebas*) of 500 ha and 3,000 ha were assigned, and the maximum size of land titles was extended up to 72,000 ha (Toni 1999). This supported the creation of capitalized oligarchies through political patronage relationships (Alston *et al.* 2000), and led to frontier expansion as described by the capitalist penetration thesis (Browder *et al*. 2008). Moreover, the lack of governance permitted the capitalized actors to develop effective strategies to appropriate and legitimise their access to natural resources (Fearnside 2008), as described in the hollow frontier theory and the invasive forest mobility model (Browder *et al*. 2008). The outcome has been intense deforestation, uneven wealth distribution and violent conflict (Alston *et al*. 2000; Sauer 2005). In fact, the study area is well known for the assassination of social leaders, such as Sister Dorothy Stang in Anapú and Ademir Federicci in Medicilândia, among others, for opposing the interests of prominent cattle-ranchers and land-grabbers. Land accumulation by large-scale ranchers (Hecht 1985) has reshaped the originally smallholder-oriented settlements (Mahar 1989; Ludewigs *et al*. 2009; Godar *et al*. 2012). In spite of this dynamic, the Transamazon Highway is still considered as a populist frontier dominated by settlement programs for small farmers (Pacheco 2005; Aldrich *et al.* 2006; Brandão and Souza 2006).

The Field Survey

The field survey was performed during 2007 and consisted of 93 questionnaires filled in during field interviews. The survey was intended to include all relevant actor groups mentioned in the literature regarding development frontiers in the Amazon. Through personal communication with representatives of actor-related organizations in the region, a list of colonists was drawn up according to: *i)* type of predominant product (permanent crops, cattle, annual crops, diversified farmers and loggers), *ii)* subjective perception of capitalization (subsistence-oriented, non-capitalized, low-capitalized, and highly capitalized), *iii)* approximate property size, *iv)* spatial distribution to optimize logistics and representativeness. The loggers contacted refused outright to collaborate. However the rest of the colonists were cooperative, including large-scale cattle ranchers illegally occupying land.

To avoid bias in the selection of colonists, the families visited were selected randomly from all the secondary roads of the four municipalities. Following Granchamp Florentino (2001), the family group rather than an individual filled out the questionnaires in order to gain a better understanding of long-term strategies and decisions, such as migration itineraries and permanence in a given location. A questionnaire was presented to the head of each family, when possible in the presence of the conjugal partner. In 14 cases the selected family was absent and they were substituted by "first opportunity" interviews (Perz *et al.* 2006) following consultation with local field assistants.

The questionnaire consisted of 38 questions in five thematic blocks (Table 2): (1) *personal background and migration itineraries* captured personal details about the family and explored their background and migration history; (2) *property description and composition* asked about the number and sizes of the properties owned and the composition of land uses. Property boundaries were obtained with a handheld GPS, and land-cover composition reported was double-checked with land-cover maps obtained from Landsat satellite images (Godar *et al*. 2012); (3) *socio-economic aspects* explored the pool of income sources, the number of people economically dependent on the property, as well as the amount and purpose of credits obtained since arrival; (4) *production* explored information on the production system including estimates of inputs and outputs; and lastly (5) *environmental performance*, specifically deforestation.

The questions were asked in a structured conversation that also included the exact formulation of all 38 questions. Answers were documented immediately during the interview, and the written information was double-checked with the colonists to assure correct understanding.

Data Analysis

The quantitative data obtained in the survey were analyzed using an exploratory factor analysis, which reduced the number of parameters that potentially discriminated between actors. The results of a principal components

Table 2 Principal issues considered in the questionnaire

Thematic Block	Focus of Questions
Personal background and migration itineraries	Name; number of family members; marital status; place of residence (rural property or city); place of birth and origin; occupation in the place of origin; previous experience in farming; initial capital; date of migration to the region; date of acquisition/occupation of the property; means of property acquisition (INCRA, inherited, purchased, occupation); legal status (title, provisory title, purchase contract, no document).
Property description and composition	Property size; number of properties owned; historical divisions or expansions of owned properties (year, total increase/decrease); reason to increase/decrease property size; distance to the main road; distance to the main market; land use at the time of acquisition/invasion; land use composition in 2007 (primary forest, secondary forest, pastures, agricultural land (permanent and non-permanent cultivations); area of cocoa plantations.
Socio-economic aspects	Number of persons economically dependant on the property; credits obtained (source, amount, year, purpose, current status); main source of income (in percentage: agriculture, ranching, logging, NTFP, non-farming jobs, social benefits, others)
Production	Number of cattle, cocoa, other perennial crops, annual crops, timber plantations, use of non-timber forest products; use and management of areas of natural forest cover, soil fertility and access to water (perceived, scale); managerial aspects (kilometres of fences, vaccinations, dairy production, salt for cattle, rotational grazing, use of fire, fertilizers, pesticides), production means (vehicles, machines, relevant tools); principal workforce (family, hired work, casual labour); contracted working hours per year.
Environmental performance	Total deforestation; respect for legal obligations (to maintain at least 80% (formerly 50%) of the property area forested (*reserva legal);* perceived degradation and erosion problems

analysis (PCA) were used to determine the more important variables in differentiating and characterizing the different actor types. The scores obtained in the PCA for each interviewed colonist were used to perform a hierarchical cluster analysis of the 93 sampled properties. We used Ward's method (1963), in which all possible pairs of clusters are combined and the sum of the squared distances within each cluster is calculated. The combination that gives the lowest sum of squares for all the clusters is chosen. This creates a hierarchy according to the similarity between pairs of observed elements. Hierarchical clustering requires a certain degree of familiarity with the data to be able to decide where to cut the hierarchy (number of clusters) and how to interpret the resulting groups. The hierarchy was depicted in a dendrogram.

In a second step, the survey data regarding the production type and the capitalization level for each property were carefully checked to evaluate the likelihood of their membership in the cluster. This assessment was also supported by reviewing the field notes. The main descriptive statistics for the questionnaires, which were aggregated according to the classified colonist types, were analyzed and compared to label and characterize each of the different colonist groups. Instead of arithmetic means strongly influenced by outliers and based on assumptions that are often not met in practice, such as normality, more robust estimators such as the median and the median absolute deviation were used to better represent central tendency. Finally, the qualitative information of the survey was used to further describe the classified groups and to provide relevant complementary information. All statistical analyses were performed using the statistical software R (R Development Core Team 2005).

Classification of Colonists

The exploratory factor analysis reduced the 38 initial questions to only eight parameters relevant for classifying colonists. However, the PCA applied subsequently revealed the importance of the area of perennial crops, the area of annual crops, the number of cattle, and the amount of hired labor as the most discriminating variables. The remaining quantitative parameters offered only redundant information. In accordance with the results presented in Table 3, most of the variance was explained by the first three principal components (PCs). PC1 reflects the degree of dependence on cattle-based mono-cultivations, as it presents a very high positive correlation with the area of pasture and the number of cattle, while clearly it is not correlated with permanent and annual crops. The area of annual crops is the only factor negatively correlated with PC1, indicating that annual crops are not important in cattle-based properties. PC2 reflects the dichotomy between labor-intensive productive strategies that include perennial crops and those based on extensive cattle ranching mono-cultivations. Higher correlations are found with areas of perennial crops and the number of individuals that are economically dependent on the property. Concomitantly, PC2 is negatively correlated with the pasture area, the number of cattle and the total area. PC3 is

Table 3 Principal component matrix of the main discriminating parameters of the field questionnaires

	PC1		PC2		PC3		
	Eigenvector	R	Eigenvector	R	Eigenvector	R	h^2
Permanent cultivations	0.03	0.05	0.66	0.91	0.11	0.11	0.84
Annual cultivations	−0.07	−0.12	0.03	0.04	−0.10	−0.11	0.97
Number of cattle	0.57	0.92	−0.22	−0.30	0.01	0.01	0.95
Hired labor	0.46	0.74	0.33	0.46	−0.10	−0.10	0.80
Pastures	0.54	0.87	−0.25	−0.34	−0.07	−0.08	0.89
Secondary forest	0.16	0.26	0.05	0.07	−0.80	−0.85	0.83
People supported	0.14	0.23	0.58	0.80	−0.01	−0.01	0.71
Credit	0.34	0.56	−0.01	−0.01	0.57	0.61	0.69
Eigenvalue	2.62		1.89		1.15		
Cumulative %	32.71		56.33		70.68		

h^2 represents the respective communalities

dependent on the relationship between access to credit and the area of secondary forest. Although PC3 presents interesting possibilities for understanding management decisions, PC1 and PC2 in accordance with the observations in the field and the literature review, are considered to be much more appropriate to distinguish between the two predominant generic strategies of colonists in the region, large-scale cattle ranching and family agriculture.

The hierarchical clustering of the PC scores revealed a cophenetic correlation of 0.74. The first three hierarchical rows of nodes were considered (Fig. 2). In the first row, three well-defined clustered blocks were obtained. Reconciling the information from the questionnaires, they were interpreted as low-capitalized colonists (A), capitalized cocoa producers (B) and cattle ranchers (C).

In a second clustering stage it was possible to further refine these groups. The low-capitalized colonists (A) were split into three subgroups with specific productive vocations (Table 4): A1) diversified farmers cultivating an average of 12 ha of cocoa, 3 ha of annual crops and who own about 38 head of cattle; A2) cattle ranchers with a considerable number of cattle (179 head), reduced areas of annual crops and who are not involved in the production of cocoa; and A3) subsistence producers with a significant number of cattle (25 head), involved in the cultivation of annual crops (2 ha), but not working with perennials. In contrast to the other subgroups, they do not have the resources to hire labor and have less access to credit. Regarding the block of capitalized cocoa producers (B), two subgroups were identified, but not separated, since both represent colonists with similarly low

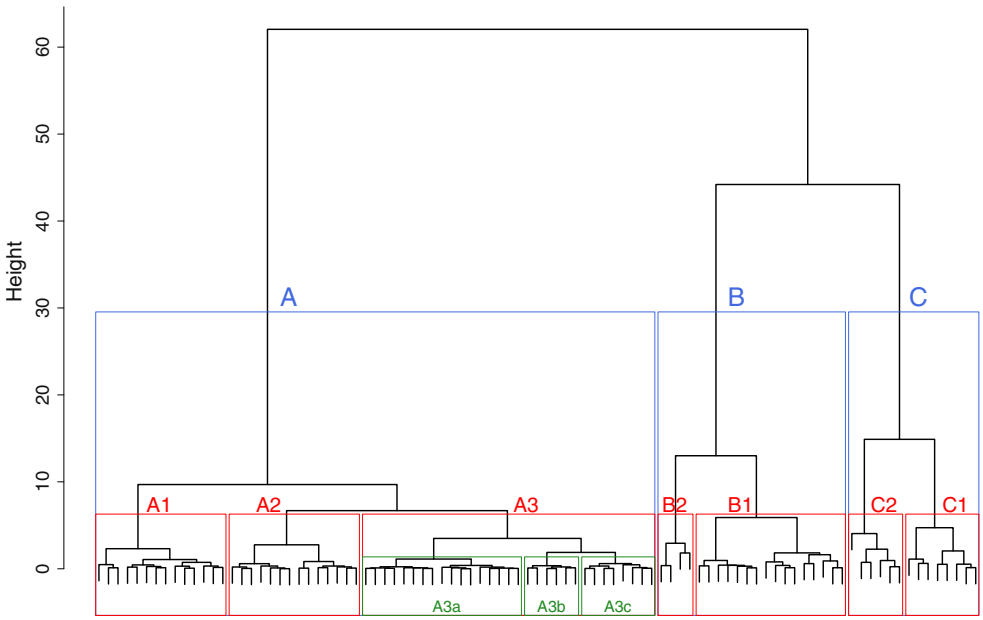

Fig. 2 Cluster dendrogram of the questionnaires. C2, large-scale cattle ranchers; C1, capitalized cattle ranchers; A2, low-capitalized cattle ranchers; B1 and B2, capitalized cocoa producers; A1, low-capitalized diversified farmers; A3a, subsistence-diversified farmers; A3b subsistence cattle ranchers; A3c subsistence farmers (annual crops)

Table 4 Main characteristics of the classified actor groups

		Cattle-ranching			Agriculture				
		Large-scale cattle ranchers (C2)	Capitalized cattle ranchers (C1)	Low-capitalized cattle ranchers (A2)	Capitalized cocoa producers (B)	Low-capitalized diversified farmers (A1)	Subsistence-diversified farmers (A3a)	Subsistence cattle ranchers (A3b)	Subsistence farmers (annual crops) (A3c)
Migration itineraries	Year of arrival *	1976	1977	1980	1972	1978	1979	1979	1985
	Area of origin (South of Brazil, %)	83.3	100	64.2	60.0	42.8	29.4	50.0	37.5
Property description	Size (ha) **	2118±866	517±137	211±102	141±53	118±56	95±18	106±62	77±28
	Size range (ha)	1121–3300	290–740	100–500	89–206	20–200	34–112	50–218	57–116
	Land increase (ha) **	650±384	150±158	60±61	25±45	9±29	0±0	−17±41	−8±21
	Distance to road (km) **	43±20	19±16	10±13	5±3	7±7	10±6	18±24	22±11
Land use composition	Mature forest (%) *	39±13	15±7	25±11	20±12	35±16	58±7	55±8	65±8
	Secondary forest (%) *	0±0	0±0	4±4	10±10	7±5	12±8	1±1	10±5
	Pastures (%) *	55±8	80±1	69±13	15±15	22±8	20±5	40±5	5±5
Socio-economic aspects	Economic carrying capacity * [a]	0.5±0.2	1.3±0.2	2.9±0.9	12±4.3	9±2.9	5.7±1.3	2±0.4	6±1.7
	Day's wages (R$) * [b]	2095±930	830±400	75±65	1275±683	415±405	0±20	35±35	0±0
	Credit (thousand R$) * [c]	101.2±79.2	99.4±99.4	30.2±5.8	46.9±46.9	28.0±5.8	28.0±6.4	11.1±11.1	0±0
Production	Cattle (N) *	1450±150	700±50	179±59	30±30	38±22	35±19	50±13	2±2
	Perennials (ha) *	0±0	0±0	0.5±0.5	36.5±6.5	12±3	3±2.5	0±0	3.8±1.5
	Annuals (ha) *	0±0	0±0	1±1	0±0	3±3	2±1	1.3±1.3	3±2
Environmental performance	Deforestation (ha) *	1090±193.0	439±74.0	150±50.0	95±17.5	64±29.0	42±8.0	52.5±21.5	27.5±11.5
	% Deforested *	50.1±14.0	73.0±2.9	51.9±16.9	52.5±35.0	42.9±17.7	40.9±10.1	37.5±12.5	26.3±14.8
	Respect of the 50% law (%)	25.0	0	7.1	0	35.7	82.4	66.7	75.0

* Median±median absolute deviation

** Mean±standard deviation

[a] Measured in persons economically supported by a property, per 100 ha

[b] In R$ of 2007 paid yearly. 1 US$=1.9 R$ aprox during fieldwork (2006–2007)

[c] In thousands of R$ at 2007 values

property sizes, good access to credit and use of hired labour, and only differed in the total area of cocoa plantations, however, in both cases, comprising large plantations of over 30 ha. The last cluster denominated as cattle ranchers (C) was divided into two subgroups differing in production scale: capitalized cattle ranchers (C1) had approximately 700 head of cattle and an average of 500 ha of land, whereas large-scale cattle ranchers (C2) typically owned about 1,500 head of cattle on more than 1,500 ha.

A third clustering stage permitted further refinement of the classified subgroups. However, such differentiation was only meaningful for the cluster of subsistence colonists (A3), which was too broad and unspecific to adequately reflect the array of subsistence strategies. Thus, three subclasses were defined on the basis of a detailed case-by-case analysis of all properties, confirmed by the statistical findings (Table 4): subsistence-diversified farmers (A3a), subsistence cattle ranchers (A3b), and subsistence farmers (annual crops) (A3c).

Figure 3 shows the final eight clustered groups and the parameters used in the PCA in a scatterplot of the two first principal components. It also summarizes the main characteristics of the groups classified above (see next section). The Euclidean distance between the PCA axes and the groups indicates the relationships between them; hence the capitalized cocoa producers sustain more people than the cattle ranchers, and that capitalized and large-scale ranchers depend more on credit than any other group. The pasture land and the number of head of cattle are clearly oriented in a similar direction from the bi-plot origin, reflecting certain linearity between them that indicates a low capacity for increasing productivity when farming area increases. In contrast, low-capitalized actors are strongly dependent on annual crops regardless of which productive vocation they represent. This indicates the importance of annual crops for family food security.

Characterization of Colonist Types

The survey data were aggregated to determine specific group characteristics of personal background and migration itineraries, property, production systems, land use compositions, financial and socio-economic aspects and environmental performance.

Personal Background and Migration Itineraries

Most of the cattle ranchers, regardless of their current capitalization level, came from the south of Brazil, including 64% of the low-capitalized ranchers (A2), 83% of the large-scale cattle ranchers (C2) and all the capitalized cattle ranchers (C1). In sharp contrast, a large proportion of the colonists from the poorer Northern states tend to focus on agriculture. More than 70% of the subsistence-diversified farmers (A3a) and 50% of the low-capitalized diversified farmers (A1) came from Northern Brazil.

The more capitalized colonists in 2007 had arrived in the region relatively early. In particular, successful cocoa producers (B) arrived around 1972 during the peak of government settlement projects and remained on their original properties. Most of the farmers who arrived much later, when most of the land close to the road was already occupied, have not managed to capitalize. Typically, they became subsistence farmers focused on annual crops (A3c).

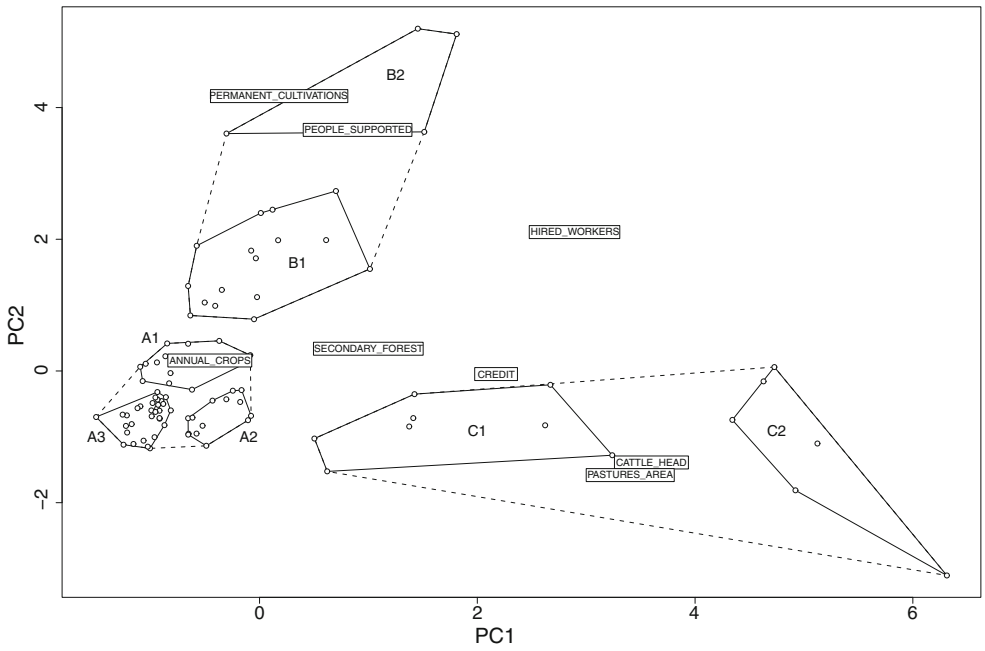

Fig. 3 Representation of the clustering results and principal components analysis variables with respect to the two first principal components. C2, large-scale cattle ranchers; C1, capitalized cattle ranchers; A2, low-capitalized cattle ranchers; B1 and B2, capitalized cocoa producers; A1, low-capitalized diversified farmers; A3, subsistence colonists

Remarkably, the numbers of colonists who acknowledge having arrived with appropriate capital are similar across all categories, ranging between 20% and 35%. Nearly all the non-capitalized colonists had experience in agriculture prior to settlement, while none of them had previous experience as mid- or large-scale cattle ranchers. In contrast 54% of the capitalized and large-scale cattle ranchers (C1 and C2) had previous experience in ranching.

Nearly 64% of the capitalized and large-scale cattle ranchers (C1 and C2) illegally occupied their land or illegally purchased land from land-grabbers. Nevertheless, 50% of them formally applied to the government authorities to get their land tenure legally recognised. In contrast 78% of the families belonging to groups A and B obtained their properties through the government or purchased properties with legal land titles. Interestingly, 90% of the large-scale cattle ranchers interviewed (C2) lived in the city of Altamira and not on their properties, while 71% of the capitalized cattle ranchers (C1) and more than 80% of all other colonists lived on their properties.

Property Description and Composition

Large-scale ranchers (C2) occupied properties of more than 2,000 ha on average, which is four times more than capitalized cattle ranchers (C1) and 10 times more than low-capitalized cattle ranchers (A2). The other actors, with the exception of the subsistence farmers (A3), typically still owned properties slightly bigger than the 100 ha distributed during initial colonization. Only some capitalized cocoa producers (B) held considerably larger properties, while most subsistence farmers (A3) had significantly smaller areas below 100 ha. Thus, one large cattle rancher (C2) occupies an area that potentially would provide the livelihood basis for more than 22 families of subsistence-diversified farmers (A3).

The survey revealed a dynamic process of land accumulation. While cattle ranchers regardless of their size and level of capitalization had considerably expanded their properties on average between 40% and 44% since arrival, no other actor groups significantly increased their land holdings. In fact some of the subsistence colonists, in particular those more recently arrived and poorer colonists cultivating annual crops, even lost parts of their land. This situation is especially problematic for subsistence cattle ranchers (A3b) because their production schemes depend on the continuous transformation of forests into new pasture land. Often, these families suffered financial problems and were forced to divide or sell parts of their properties. In comparison, farmers following a diversified subsistence strategy (A3a) generally managed to maintain their initial areas.

The different actor groups showed significant differences with regards to the location of their properties. Large-scale and capitalized cattle ranchers (C1 and C2) were mostly situated far from the highway at an average linear distance of 43 km and 19 km respectively, where they can expand their land more easily than in already consolidated properties nearer the main road where most of the low-capitalized cattle ranchers (A2) and cocoa and diversified producers (A1 and B) settled. The more recently arrived subsistence farmers settled further away from the road where cheap land is still available.

Finally, the analysis also confirmed structural differences between the actor groups regarding land use. In the extremes, the subsistence farmers focusing on the cultivation of annual crops converted 35% of their land, whereas capitalized cattle ranchers maintained only 15% of the original forest cover. In general, colonists focusing on the production of cattle preserved less mature forest per area unit than those with more diversified strategies, regardless of whether they were capitalized (15% vs. 20%), low-capitalized (25% vs. 35%) or subsistence colonists (55% vs. 58% and 65%, respectively). Cattle ranching colonists also had significantly less secondary forests than the more diversified producers. Considering that secondary forests play an important role in restoring soil fertility (Scatena *et al.* 1996), this suggests that most cattle ranchers created their pasture land through the direct conversion of mature forests, whereas farmers and diversified producers seem to periodically convert secondary forest into farm land as part of a fallow-rotation cycle. While pasture dominates in the cases of large-scale cattle ranchers (55% of total land), capitalized cattle ranchers (80%) and low-capitalized ranchers (69%), the land use composition of the remaining actors was more diverse.

Socio-economic Aspects

Agriculture (crop production) generated on average more than 48% of the income of the colonists interviewed, whereas cattle ranching accounted for less than 36%. Nevertheless, ranching was typically less important for the majority of colonists because the median was only 20% of total income. Salaries obtained from off farm activities accounted for nearly 10% of total average family income, while timber and non-timber forest products represented less than 0.5% of total income.

Regarding the economic carrying capacity referring to the number of individuals directly depending on a specific property, as an indicator of the socio-economic importance of the productive schemes, the analysis showed that capitalized cocoa producers (B) and low-capitalized diversified farmers (A3a) sustained significantly more people per property (15 and 10 people respectively) than the groups of largeholders interviewed. In relative terms per 100 ha, a low-capitalized diversified farm (A3a) sustained seven

times more people than a capitalized cattle ranch (C1), and almost 18 times more than a large-scale cattle ranch (C2).

The capacity to hire non-family labour was strongly related to the level of capitalization but also to the productive strategy. For example large-scale cattle ranchers (C2) typically paid on average the equivalent of 2,095 daily wages a year, while capitalized cocoa producers (B), in spite of their significantly smaller properties, paid around 1,275 daily wages a year. These numbers confirm that relatively few people can manage large herds of cattle, one of the main reasons why cattle are so popular among colonists and explains why ranching is still one of the fastest growing activities in the region. Most of the other colonist types did not have the financial capacity to hire permanent outside labour. However, most of the cocoa producers and diversified farmers managed to contract some workers for specific seasonal tasks. Commonly, when a cocoa plantation exceeded the capacity of family labor, so-called *meeiros* are contracted to manage a part of the plantation, receiving half of the generated benefits on a share cropping basis.

Despite the good performance of colonists applying diversified production schemes or planting cocoa (Godar *et al*. 2012), most public credits were designated to cattle ranching. The larger cattle ranchers interviewed (C1 and C2) received on average approximately R$ 100,000 representing more than double the amount of a capitalized cocoa producer (B), and four times more than a low-capitalized diversified farmer (A3a). Surprisingly the rates of defaults on loan payments, expressed by the proportion of colonists that paid less than 10% of the total loan at the time of the interview, were much higher among the large-scale ranchers (60%) and capitalized ranchers (50%) compared to cocoa producers (25%) and low-capitalized diversified producers (27%).

Production

All large-scale and capitalized cattle ranchers interviewed had homogeneous production systems exclusively oriented to cattle ranching (with an average of 1,450 head for C2 and 700 head for C1 respectively), with virtually no land dedicated to perennial or annual crops. Also the low-capitalized cattle ranchers (A2), strongly focused on cattle, with an average of 200 animals, but they also cultivated annual crops for domestic consumption. In this sense, the area of annual crops seems to be a good indicator for the level of capitalization of ranchers. The remaining actors showed more diversified production strategies independent of their level of capitalization, often including cattle ranching. The finding that colonists with such diverse levels of capitalization maintain similar numbers of cattle suggests that for a colonist family with 100 ha of land, a herd of around 30 animals presents an acceptable trade-off between management costs, opportunity costs of the land, and benefits related to income generation and risk reduction.

Virtually none of the colonists invested in the commercial use of forest products. This generally low level of interest in forestry may result from their agricultural background and origin from already deforested regions, but may also reflect the strong incompatibilities between the complex and bureaucratic requirements for legal timber production and the colonists' labour capacities (Amacher *et al.* 2009; Medina *et al.* 2009). Soil fertility and water accessibility were not generally considered as problematic production factors. Only producers of cocoa and other perennial crops stated that soil fertility is a decisive requirement for productive success. As a consequence, capitalized cocoa producers (B) had access to at least some areas of higher fertility (*terra roxa*), while subsistence farmers (A3) were mainly found on areas with lower soil fertility (*terra branca*) and, consequently, fewer land-use options. Cattle ranchers were settled more randomly in areas with high and low fertility soils.

Environmental Performance

The socio-economic strategies of the different actor groups were found to be correlated to their environmental performance, with cattle ranchers being clearly responsible for greater deforestation. The scale of land clearance is related to the degree of capitalization among cattle ranchers and farmers, respectively. Every large-scale rancher was responsible, on average, for 1,090 ha of deforestation, with capitalized and low-capitalized ranchers also presenting high deforestation values of 439 ha and 150 ha, respectively. In contrast, the diversified and subsistence-oriented colonists were responsible for comparatively lower levels of deforestation. A family of subsistence farmers focused on annual crops (A3c) deforested less than 30 ha, whereas a capitalized cocoa producer (B) on average was responsible for the deforestation of nearly 100 ha.

If all the properties corresponding to each classified group of colonists are aggregated, only the low-capitalized diversified farmers (A1) and subsistence groups (A3) respected the original legal limitation of deforesting less than 50% of the property. If considering individual compliance the only group of colonists where the majority of colonists respect the law is that of subsistence farmers (A3). In fact, no single capitalized cocoa producer (B) or capitalized cattle rancher (C1) complies with the law. Despite the enormous size of their properties, only 25% of the large-scale cattle ranchers maintained forests on more than half of their property. As a consequence of the high deforestation rates, more than 51% of cattle ranchers noticed significant erosion on their property affecting productivity. In contrast, less than 25% of other colonists mentioned erosion on their properties.

Discussion and Conclusions

The statistical methodology for colonists' classification we have presented indicates that a meaningful classification of colonists settling along the Transamazon Highway should at least consider: (1) property size; (2) information about the production system, in particular the area cultivated with perennial and annual crops, as well as the number of cattle; and finally, (3) the number of workers hired in addition to family members. It is also useful to consider the areas of origin of the colonists, since to a certain extent this influences the productive strategy and the level of capitalization. The interviews revealed, for example, that most of the cattle ranchers were from southern Brazil, a relatively wealthy region where cattle ranching is predominant. Obviously, many of these colonists had the necessary skills and resources to acquire larger areas of land, effectively access credit and thereby replicate the productive models from their home region. In contrast, the families from Northern Brazil had usually practiced subsistence agriculture and experienced extreme poverty. As a consequence, they opted for subsistence-oriented agricultural production schemes not requiring large initial investments. In this sense, the colonization process seems to mimic the socio-geographic background of the settler families, traditionally characterized by extreme regional inequalities in Brazil (Azzoni 2001).

Expansion Versus Consolidation

Cattle ranchers were the only colonists systematically increasing the size of their properties, suggesting that land accumulation is an intrinsic characteristic of profitable cattle ranching. This is in accordance with the results obtained by Godar *et al*. (2012) using a large dataset of georeferenced properties. The smallholders, in contrast, were strongly linked to their properties and focused more on the effective use of available resources on the original area of the property. In this sense, our study confirms the observations of Siegmund-Schultze *et al.* (2007) that for most smallholders, agriculture is far more attractive than cattle ranching. In fact, the low level of well-being of small subsistence cattle ranchers indicates that cattle ranching mono-cultivations are incompatible with small properties in the Transamazon Highway. In contrast to the findings of Walker *et al*. (2000), in our study area cattle ranching is only a secondary additional productive component for smallholders due to its liquidity, and it is used as an alternative financial asset that demands low management input. None of the smallholders interviewed were interested in expanding the area dedicated to cattle in their current properties, and kept an average of just over 30 head of cattle. In this sense, probably it is mainly the predominant focus of public credit incentives on cattle (Toni 1999; Costa 2000b) that may create the impression that this production component plays a key role for smallholders in the Transamazon Highway.

The Importance of Access to Urban Centers

The continuous demand for new land also explains why most of the large-scale and capitalized ranchers were found at a considerable distance from the main road, as the greater availability of land and the lower level of law enforcement facilitates land appropriation and occasional expansion as the productivity of pasture declines. As a consequence, cattle ranchers situated in areas closer to the road lacking these conditions consistently presented low levels of capitalization. On the other hand, subsistence colonists are situated further from the road compared to more capitalized smallholder groups. This clearly indicates the crucial importance of access to urban centers, in this case mainly the city of Altamira, in providing market opportunities and basic services (Becker 2005). Moreover we found that family members often left their rural properties for the city, strengthening the socio-economic linkage of colonists to the urban centers (Barbieri and Carr 2005; Padoch *et al*. 2008). This phenomenon, in conjunction with the process of land accumulation, is contributing to an intensive urbanization dynamic, accelerating social differentiation between subsistence and middle class colonists in frontier towns (Coy 1992), and potentially influencing the environmental impacts of each type of farmer (Eloy and Emperaire 2011). It is estimated that more than 70% of the population of Northern Brazil is already living in cities (Becker 2005).

How Small is a Smallholder?

This study demonstrates that property size alone does not permit sufficient differentiation between small and largeholders. Nevertheless, compared to other quantitative parameters, it is relatively easy to measure and is correlated to some decisive features of the colonists. Therefore, the property size should remain one of the most important parameters for the classification of colonists. However, as outlined above, the thresholds for property size generally used for distinguishing between small and largeholders are inconsistent and do not necessarily reflect local realities. Considering that, in accordance with our data, cattle ranching requires almost 600 ha to achieve an economy of scale, and that 82% of the properties in the four municipalities included in this study were smaller than 200 ha (Godar *et al*. 2012), thresholds used by some authors (e.g., Aldrich *et al.* 2006) would inevitably amalgamate a wide range of colonist types representing significantly different production strategies. Practical and locally adapted size thresholds can be obtained from the actor's classification methodology presented here (Fig. 4). In

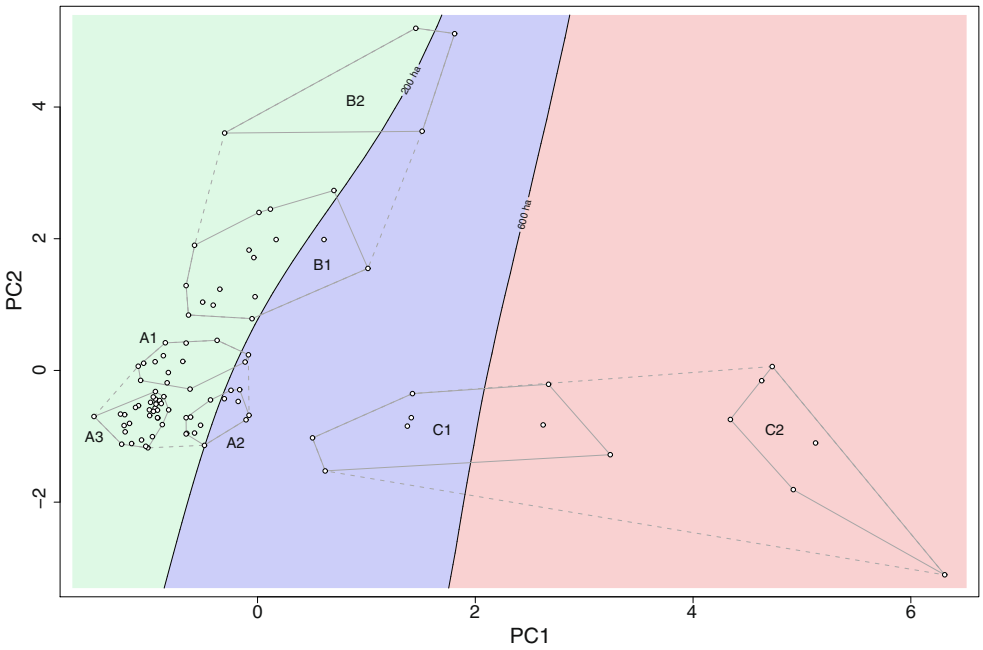

Fig. 4 Representation of the colonist's samples in the first two principal components and trend surface mapping of total property area. The colored regions correspond to the size thresholds defined for smallholders (*green*), medium landholders (*purple*) and largeholders (*red*). C2, large-scale cattle ranchers; C1, capitalized cattle ranchers; A2, low-capitalized cattle ranchers; B1 and B2, capitalized cocoa producers; A1, low-capitalized diversified farmers; A3 subsistence colonists

particular most smallholders, including subsistence and low-capitalized colonists relied on properties of less than 200 ha in which a diverse range of products were obtained, while nearly all colonists with more than 600 ha focused exclusively on large-scale cattle ranching. Capitalized and low-capitalized cattle ranchers were found in properties of between 200 ha and 600 ha, but due to the limitation in resources they can be identified as medium sized.

Environmental Impacts

Our findings show a strong relationship between the level of capitalization and the maintenance of mature forest remnants. The more capitalized actors converted most of their forests into farmland, whereas subsistence farmers maintained mature forests on average on more than half of their properties. All colonists specialized in cattle ranching, independently from their level of capitalization, showed a clear tendency to gradually convert their entire property into pasture, eventually expanding to new areas and thereby strongly accelerating the deforestation process. In our study area, an analysis of satellite images revealed that 53% of the total deforestation can be attributed to large and capitalized cattle ranchers with properties above 200 ha, while colonists owning up to 100 ha only contributed 23% to total deforestation (Godar *et al.* 2012). Our data are in accord with the deforestation assessments of Fearnside (1993), Alencar *et al*. (2004) and Chomitz and Thomas (2003) for the whole Brazilian Legal Amazon, while standing in sharp contrast to a number of other studies (Homma *et al.* 1995; Faminow 1998; Margulis 2003; Pacheco 2005; Aldrich *et al*. 2006).

Perverse Incentives

Our study attested a lower contribution of cattle ranchers to social welfare if compared to diversified family agriculture. This suggests that there is probably a better chance of creating inclusive rural development by promoting family agriculture rather than cattle ranching in our study area. However, as seen in Table 4 most incentives, in the form of credit, were directed towards cattle ranching (Toni 1999; Godar 2009). As a consequence, smallholders are obliged to invest in cattle to access available credit, disregarding considerations of profitability or other farm diversification strategies. In addition, this suggests that the economic wealth of large-scale and capitalized cattle ranchers measured by the number of head of cattle is more likely to reflect the amount of credit received than the financial viability of ranching itself. This is refuted by Margulis (2003), but the default rates on loan repayments in our study area are highest for large-scale and capitalized cattle ranchers, indicating that smallholders cultivating perennial and annual crops have fewer difficulties generating the financial returns required to pay back loans. This hypothesis is supported by the case of one interviewee who, illegally acquired more than 3,000 ha of land and was granted several successive loans for a total of approximately 55,000 US$. He currently enjoys the status of a large-scale rancher without ever generating substantial profits. Revealingly, he freely admitted to not being able to pay back the loans and to have started to invade new land to sell it to newcomers, thereby improving his precarious financial situation to eventually reinvest in more cattle.

Final Considerations

The methodological approach we have presented has proven to be a successful instrument for the classification and characterization of Amazon colonists in a replicable and standardized way. Although actor classifications need to be locally adapted given the large diversity of contexts in the Amazon, our approach can contribute to the generation of information to improve differentiation among Amazonian colonists and understanding of their productive strategies and associated effects on the environment and local economies. In view of the fact that in our study large-scale cattle ranchers are the principal actors responsible for frontier expansion and deforestation, policies should stop promoting cattle ranching, and should instead support diversified family agriculture more systematically. A profound review of the legal and institutional framework for the development of the Amazon is then necessary. Given the limited size of our sample, broader studies are needed. Additional research in other locations would permit the further adjustment of the proposed methodology and include actors not present in the Transamazon Highway.

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