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3 Agribusiness and Socioeconomic Drivers of Land Cover Change in Brazil

3.1 Conceptual Framework of Economic and Social Drivers for Land Use Change

3.1.1 Population Growth, Industrialization and Agricultural Technology

Human history evidenced the advance of croplands over natural areas to meet the needs for food, fibers and fuels (Grigg, 1982). The gloomy predictions of human demographic models pointed out population increase as a determinant driving force for poverty, starvation (Malthus, 1798) and also for depletion of natural resources (Meadows et al., 1972). Population growth (Fig. 3.1 – box at rightmost section) affects rural land use through multiple and sometimes opposite pathways. Changes in economy patterns, from agriculture dominant to industry and services based, induce urban populations to increase faster than rural ones. Migration to developing cities reduces the availability of rural labor (Fig. 3.1 – boxes at bottom left corner), what increases the labor costs for maintenance or expansion of cultivated lands (Rudel et al., 2005).

The investment decisions in farmlands rely on the relative costs of the factors of production (Angelsen et al., 2001), namely land (farmland, natural resources), labor (human work) and economic capital, which includes built capital (facilities, machinery) and financial capital (Fig. 3.1 lower dashed box). The growth of urban population fosters the expansion of cities over surrounding rural areas, what contributes to inflate the rural land prices (Livanis et al., 2006). As well as labor costs, the increase of land price also changes the relative agricultural costs. This scenario favors the investment in labor-saving and land-saving technologies, such as mechanization and fertilization of croplands respectively (Angelsen et al., 2001).

In the 1960 decade, the Green Revolution fostered new agricultural technologies that allowed increasing the productivity of croplands. The productivity increase roughly balanced the supply and the demand of agricultural goods. However, technology by itself, cannot endlessly expand agricultural production, and does not represent the solution for starvation or underdevelopment, given the unequal distribution of resources (Angelsen & Kaimowitz, 2001a).

Technological development can accelerate the depletion of natural resources, since the improvement of land productivity relies on intensive use of fossil fuels, freshwater, minerals, agrochemicals, and more recently on genetically modified organisms (Clay, 2004; MEA, 2005). As a consequence, highly intensified agricultural regions present environmental problems due to water eutrophication, soil compaction and salinization (Clay, 2004; MEA, 2005), and changes in species abundance which triggers pests and diseases outbreaks (Chapter 11 and 12, this book). Despite these significant environmental impacts, some Green Revolution hypotheses argue that adoption of agricultural technologies may increase the productivity in croplands and relieve the pressure of farmland expansion over remaining natural vegetation (Angelsen & Kaimowitz, 2001a; Balmford et al., 2005).

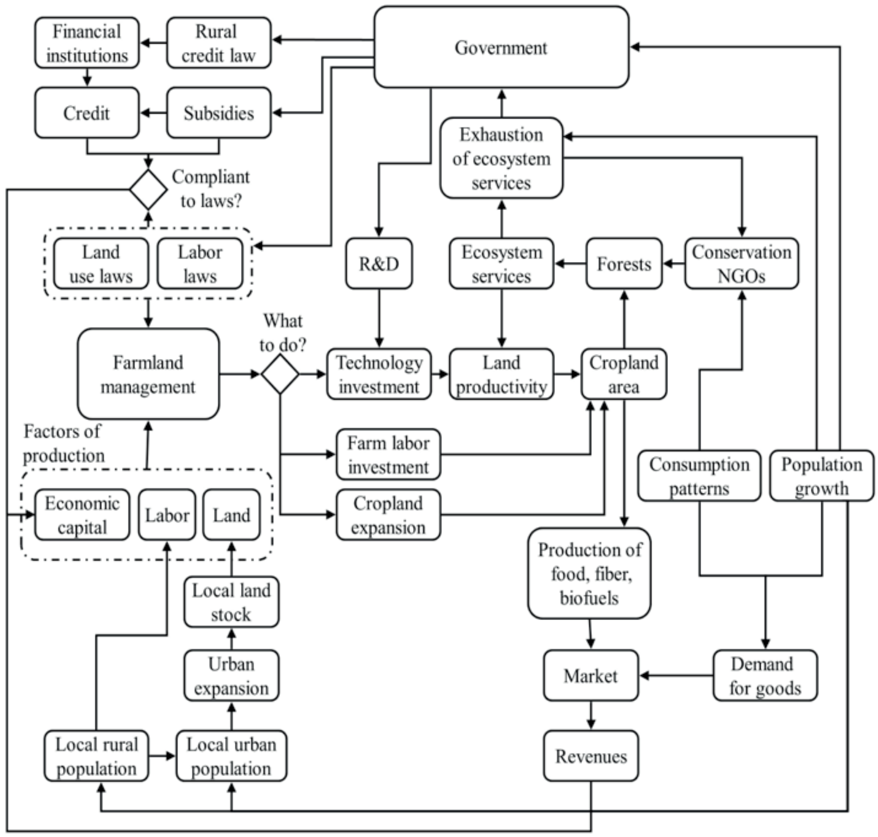

Fig. 3.1: Conceptual Framework of demographic, legal, economic and technological drivers on farm land-use management. Arrows represent the influence of one variable on another.

3.1.2 Development-based Hypotheses for Forest Recovery

3.1.2.1 Forest Transition Hypothesis

Forest Transition (FT) is a controversial hypothesis which states that urban development starts a chain of events that could lead to the retreat of cultivated areas and to forest recovery. Industrialization and urbanization would create new jobs and attract workers to the cities. Rural labor costs would increase and agriculture would concentrate in the more productive lands, allowing forest regrowth in the abandoned and less productive areas. Rudel et al. (2005) identified the scarcity of rural labor as a key driver for increase of forest area in Greece, Ireland and Portugal in the period between 1990 and 2000. Rudel et al. (2005) refer to this sequence of events, from development of the cities to forest recovery in marginal areas, as the "economic development path" in the FT hypothesis.

3.1.2.2 Agricultural Adjustment Hypothesis

Agricultural Adjustment (AA) hypothesis complements the scenario of FT hypothesis, and argues that increased labor costs would foster farmland technology, increasing agricultural production. When technology increases agricultural yields to the level of the demand for agricultural goods, Mather and Needle (1998) predict the concentration of agricultural activities in the more suitable lands, hindering farmland expansion, reducing the cultivated area, and allowing the regrowth of secondary forests in the less productive and abandoned areas.

3.1.3 Caveats on Development-based Hypotheses

Despite demographic (rural exodus) and technological local effects on limiting farmland expansion, the globalized access to markets of agricultural goods (Fig. 3.1 – boxes at bottom right corner) may increase the agricultural revenues and contribute to intensify the pressure toward farmland expansion (Angelsen, 1999). If local production is export-aimed, but does not represent a substantial international market-share, agricultural prices would be weakly reduced by local yield increase. In this scenario, where local sale price is perceived as static at any local yield level, productivity gains would increase farm profitability and stimulate the expansion of cultivated areas, even in less profitable sites (Angelsen et al., 2001). Without enforced regulatory constraints, incentives, taxes or market-based interventions, setting aside agricultural land to natural capital conservation can become unfeasible.

The material-intensive urban consumption patterns (Fig. 3.1 – right side) may leverage the effects of population growth on farmland expansion. The changes in dietary habits of the growing Chinese urban population, replacing locally produced vegetables by pork and poultry products, foster the expansion of Brazilian soybean croplands for animal feeding (Nepstad et al., 2006).

However, globalization of markets and the change of people's preferences may also play a controlling role on farmland expansion over natural areas. The growing concern about the exhaustion of ecosystem services spurred the development of environmentalist Non-Governmental Organizations - NGOs (Fig. 3.1 – boxes at top right). In Brazil, this emerging scenario shows initiatives as the Brazilian soybean roundtable and the Amazonian beef boycott. Both initiatives had as starting point the concerns of distant urban consumers about the environmental impacts of agricultural production (Nepstad & Stickler, 2008). Taking into account the risk of economic losses, transnational companies and NGOs pressed Brazilian farmers to suspend the expansion of soybean cropland on native areas, and also induced the Amazonian ranchers to comply with Brazilian environmental and land use laws.

3.2 The Conceptual Framework in Brazil

3.2.1 Native Vegetation in Private Farms and the Forest Code

Brazil is the world's fifth largest country, with an area of 8.5 million km^2, and around 32% of the land is used for agriculture. The agricultural area increased 14% between 1990 and 2011, while native forested areas declined 10% in the same period (UNSD, 2013). Expressive investments in agriculture development since the middle of the last century led the country to the third place in global exports of agricultural products. In 2012, exports of agricultural goods accounted for US$86 billion, representing 35% of Brazilian total exports (WTO, 2013).

Even so, Brazilian forests still cover 5.2 million km^2 (UNSD, 2013), an area larger than the entire European Union. However, in only five years (2000 to 2005), forest loss in Brazil accounted for 164,000 km^2 (Hansen, 2010), an area equivalent to almost half the Germany territory. Although recent conservation efforts caused the decline of deforestation rate, the conversion of forests to pastures and crops led the country to become the world leader in tropical deforestation (Hansen, 2010).

In the decade of 1960 Brazilian agriculture was losing competitiveness in traditional export commodities as coffee, sugar, cotton and cocoa, and the growing urban population was dealing with frequent shortages of basic agricultural goods as rice, sugar and beef (Igari & Pivello, 2011). To address these issues, the Brazilian National Congress passed two laws, in late 1965, with the objective of enhancing the productivity of agriculture: the New Forest Code (NFC) and the Rural Credit (RC) (Igari & Pivello, 2011). NFC was a land-use law that aimed to restrain the degradation of agricultural soils and freshwater stocks through the definition of mandatory areas of permanent preservation (commonly known as APP) which encompasses native vegetation in riparian areas, hilltops and slopes steeper than 45°. Furthermore a given percentage of the farm could not be converted to agricultural use (later on, these areas were named as Legal Reserves).

3.2.2 Agricultural Intensification and the Rural Credit Law

The RC law was approved two months after the NFC, and stated that a percentage of the deposits in the banking system would have to be invested as rural credit under subsidized interest rate (Fig. 3.1 – boxes at top left corner), in order to modernize

Brazilian agriculture (Igari & Pivello, 2011). Moreover, an intriguing clause in the RC law stated that the subsidized loans could not be conditioned to compliance with the NFC. This decoupling between subsidized loans and compliance to NFC (Fig. 3.1 - decision diamond shape at top left area) may even be interpreted as a governmental financial incentive to degrade the natural capital (Igari et al., 2009).

This early conflict between NFC and RC is reflected in the present scenario. In 2005, public subsidies to rural loans represented three times the total budget of the Ministry of Environment, the institution responsible for enforcing NFC and for the management of most Brazilian federal nature reserves. Moreover, the rural credit loans were equivalent to 44% of the agricultural added value to Brazilian Gross Domestic Product (GDP) in 2008 (Igari & Pivello, 2011).

The financial support provided by RC was preceded by a governmental program to foster domestic production of industrialized goods, which benefited the farm equipment industry. In 1960, imports supplied all farm equipment in Brazilian agriculture, but three years later, there already were six national companies, with total production capacity of 21,600 units per year (Vegro et al., 1997).

The local development of agricultural technology gained *momentum* in 1973, when the federal government created EMBRAPA, the national agency for research on agriculture and cattle raising (Fig. 3.1 – R&D box), which was the main responsible for successful adaptation of temperate agricultural crops to the Brazilian soils and climate (Kaimowitz & Smith, 2001).

3.3 Confronting Development-based Hypotheses to Empirical Data

The broad diversity of land use patterns, of rural/urban population composition, of technological development and economic wealth among the Brazilian states offers a promising opportunity to study the relationship among the hypothesized driving forces for land use change. It is possible to identify a wide range of combinations between the extreme scenarios, from remote barren rural regions, which present large portions of pristine areas under risk of massive deforestation (Hansen et al., 2010), to developed states, where secondary forests seem to recover in rural landscapes (Baptista & Rudel, 2006). Furthermore, Brazilian demographic and agricultural surveys deliver standardized long-term data on land use, demographic and technological characteristics since the 1960 baseline (prior to NFC and RC law) until the present scenario. Moreover, sub-national approaches of land use change allow controlling the variation of government policies present in cross-national studies, what usually entangles the causation effect of the explanatory variables.

In the next section we sought to answer two questions, in order to investigate the validity of the “economic development path” of FT hypothesis (Rudel et al., 2005) and of the AA hypothesis (Mather & Needle, 1998): (a) Does the reduction of rural population lead to the lack of rural labor and then to farmland retraction and forest recovery? (b) Does the technological development in farms lead to reduction of croplands, and then, to forest recovery?

3.3.1 Empirical Data

The state-level data regarding farmland area, forest area inside farms, number of tractors (as a proxy of mechanization), and number of rural workers were extracted from Brazilian agricultural census of 1960 (IBGE, 1960a) and 2006 (IBGE, 2006). Rural and urban population data were taken from demographic census of 1960 (IBGE, 1960b) and 2010 (IBGE, 2011). The 2010 demographic census was the closest survey to 2006 agricultural census.

Rural credit data was attained from Brazilian Central Bank annual reports from 1969 to 2006 (BCB, 1985; BCB, 1999; BCB, 2012), and the average annual RC value was calculated for each state in that period. RC values were converted to US dollars (US$) through the average daily exchange rate of 2006, where US$1.00 = R$2.17 (FED, 2012).

The percentage of farmland in each state was calculated through the division of the total farmland area (in 1960 and 2006) by the official state area (IBGE, 2012). The average percentage of native forests inside farms was attained through the division of total area of native forests inside farms by the total farmland area in each state. The average level of mechanization was estimated by the number of tractors per km^2 of farmland in the state. The average intensity of rural labor in the state was estimated by the number of rural workers per km^2 of farmland. The rural and urban population data were directly extracted from the demographic census in each year.

The half century timeframe was chosen in order to capture the contribution of the RC law on farm mechanization and of NFC on conservation of native vegetation in private farms. Both laws could then foster AA and FT in Brazil. Rudel (1998) predicted a time lag of 15 to 20 years in the “economic development path” of FT hypothesis. This means that land abandonment and forest recovery would take place one generation after the urbanization-led demographic changes. The half century timeframe would then be large enough to capture significant changes in all variables. The broad-scale timeframe and the sub-national assessment were also compatible to the approach of the study conducted by Rudel (2001), in which he identified the positive effects of the Green Revolution on FT at the south of the United States between 1935 and 1975.

3.4 Empirical Results

Total results encompassing the 26 Brazilian states showed an expressive increase of the Brazilian urban population (+127 million) contrasting with a shrinking rural population (-8 million) from 1960 to 2010 (Tab. 3.1). The negative variation of the rural population is reflected on the reduction of the average rural labor intensity

Tab. 3.1: Demographic (urban and rural population), technological (rural labor and mechanization), financial (rural credit) and land-use (farmland in the state and forests inside farmlands) results concerning the 26 Brazilian states in 1960 and their variation (Δ) until the most recent survey (2010 for demographic data and 2006 for all other variables). Highlighted numbers are the three higher (+) and lower (-) values of each column. [A] Corroborate agricultural adjustment hypothesis (+ mechanization → - farmland → + forests in farms). [F] Corroborate "economic development path" of forest transition hypothesis (+ urban population → - rural population → - rural labor → - farmland → + forests in farms).

State		Urban population ($\times 10^3$)		Rural population ($\times 10^3$)		Rural labor (worker × km^{-2})		Mechanization (tractor × km^{-2})		Farmland in the state (%)		Forests in farms (%)		Mean annual rural credit (US$ $\times yr^{-1} \times 10^6$)
		1960	Δ 2010	1960	Δ 2010	1960	Δ 2006	1960	Δ 2006	1960	Δ 2006	1960	Δ 2006	1969-2006
Acre	(AC)	**34** (-)	**499** (-)	125	75	**32** (-)	253	**0.0** (-)	**1.8** (-)	62	**-39** (-)	**82** (+)	-19	**32** (-)
Alagoas	(AL)	421	1877	835	-12	**1903** (+)	240	1.7	15.4	69	7	31	**-19** (-)	267
Amapá	(AP)	35	**565** (-)	**33** (-)	35	**39** (-)	111	0.2	**0.9** (-)	9	-3	61	-14	**5** (-)
Amazonas	(AM)	237	2519	123	**602** (+)	261	**473** (+)	0.0	**2.0** (-)	**4** (-)	-2	**88** (+)	**-38** (-)	78
Bahia	(BA)	2049	8056	**3870** (+)	46	1030	-233	0.3	9.1	31	**20** (+)	25	8	913
Ceará [A]	(CE)	1103	5241	2186	-82	732	**714** (+)	0.2	7.0	**74** (+)	**-20** (-)	29	7	343
Espirito Santo	(ES)	370	2559	799	-216	987	132	1.8	40.0	63	-1	30	-15	257
Goiás	(GO)	517	4904	1077	-494	202	-39	0.7	16.8	57	19	13	8	1189
Maranhão	(MA)	443	3701	2034	392	1158	**-395** (-)	0.1	4.6	25	14	25	7	195
Mato Grosso	(MT)	139	2346	182	367	71	4	0.1	8.8	9	**44** (+)	27	12	1069
Mato Grosso do Sul	(MS)	208	1890	364	-12	57	14	0.3	12.3	65	19	14	5	859
Minas Gerais [A]	(MG)	**3914** (+)	**12800** (+)	**6167** (+)	**-3285** (-)	579	2	1.2	27.0	67	-11	**9** (-)	13	2228
Pará	(PA)	624	4573	917	**1474** (+)	637	-284	0.7	3.5	4	14	50	-10	246
Paraíba [A,F]	(PB)	695	2144	1296	-368	1359	-63	1.2	6.5	72	-5	**11** (-)	**20** (+)	189
Paraná	(PR)	1311	7595	2953	**-1420** (-)	1128	**-398** (-)	4.6	69.8	57	20	25	-7	**3761** (+)
Pernambuco [A,F]	(PE)	1828	5221	2252	-506	**2132** (+)	**-393** (-)	1.7	8.5	60	-5	19	6	448
Piauí	(PI)	292	1759	957	111	393	**482** (+)	0.1	3.9	36	2	27	**23** (+)	131

State		Urban population (× 10^3)		Rural population (× 10^3)		Rural labor (worker × km^{-2})		Mechanization (tractor × km^{-2})		Farmland in the state (%)		Forests in farms (%)		Mean annual rural credit (US$ × yr^{-1} × 10^6)
		1960	Δ 2010	1960	Δ 2010	1960	Δ 2006	1960	Δ 2006	1960	Δ 2006	1960	Δ 2006	1969-2006
Rio de Janeiro	(RJ)	**5253** (+)	**10214** (+)	1397	-870	875	-105	**5.5** (+)	31.9	69	**-22** (-)	18	-3	347
Rio Grande do Norte [A.F]	(RN)	428	2038	713	-11	812	-36	0.9	12.5	70	-9	11	20	153
Rio Grande do Sul [A.F]	(RS)	2412	6690	2976	-1383	616	-6	**7.0** (+)	**73.9** (+)	**77** (+)	-5	**10** (-)	2	**3920** (+)
Rondônia	(RO)	**31** (-)	1112	**40** (-)	378	140	193	0.3	6.6	**1** (-)	**34** (+)	**80** (+)	**-46** (-)	73
Roraima	(RR)	**12** (-)	**332** (-)	**16** (-)	90	**37** (-)	136	**0.0** (-)	2.6	**4** (-)	4	12	**35** (+)	**14** (-)
Santa Catarina	(SC)	688	4561	1441	-440	967	-21	1.9	**113.8** (+)	62	1	29	-3	1022
São Paulo	(SP)	**8044** (+)	**31508** (+)	**4779** (+)	**-3080** (-)	895	-349	**14.1** (+)	**72.9** (+)	**78** (+)	-10	12	-1	**4648** (+)
Sergipe	(SE)	291	1229	461	87	**1696** (+)	120	0.6	19.6	67	1	16	-4	115
Tocantins	(TO)	63	1094	260	**442** (+)	114	9	**0.0** (-)	6.9	35	17	21	14	178
Mean		**1209**	**4886**	**1471**	**-311**	**725**	**22**	**1.7**	**22.3**	**47**	**3**	**30**	**0**	**872**
SD		**1881**	**6273**	**1576**	**1030**	**600**	**277**	**3.1**	**28.8**	**27**	**18**	**23**	**18**	**1300**
Brazil – total		**31444**	**127026**	**38254**	**-8078**	**626**	**-124**	**2.5**	**22.4**	**29**	**9**	**22**	**6**	**22678**

(rural workers per km^2) and on the increase of average mechanization in farmlands (tractors per km^2). The mechanization increase was supported by an average annual rural credit of US$22.6 billion. Despite the reduction of rural labor intensity and the increase of mechanization, the national percentage of farmland has increased from 29% to 38% (+9%) between 1960 and 2006. In the same period, there has been an increase (+6%) of the average percentage of native forest area inside farmlands (Tab. 3.1). The standard deviation (SD) was much larger than mean values in 11 of the 13 variables considered in the analysis (Tab. 3.1), what expresses the heterogeneity among states.

The urban population has increased in all 26 states, and in several of them the increase until 2010 was one order of magnitude larger than the entire urban population in 1960 (Tab. 3.1). Meanwhile, the rural population increased in 12 states, but even in these states the increase of urban population was far larger than rural population growth (Tab. 3.1).

Rural labor intensity declined in 12 states from 1960 to 2006 and there has been an overall augment of the average mechanization in farmlands until 2006. Only 3 states (SP, RS and PR - refer to Table 3.1 for states names) accounted for more than 54% of the national rural loans between 1960 and 2006 (marked with "(+)" in Table 3.1). These three states also showed substantial mechanization increase in the same period.

The percentage of farmland declined in 12 states (Tab. 3.1). This farmland reduction does not necessarily means that forests would recover, since farmland could give place to other non-forest land uses, as mining or cities. Furthermore, from these 12 states, 6 states (AC, AP, AM, ES, RJ and SP) also showed decline in the average percentage of forests inside farms.

Despite the increase in the percentage of forests inside farms in 14 states and the overall increase of mechanization (Tab. 3.1), the land-use predictions from AA hypothesis were supported only in six states (marked with "A" in Table 3.1). Furthermore, the predictions from the "economic development path" of FT hypothesis were identified in only four states (marked with "F" in Table 3.1), although the reduction of rural labor intensity has took place in 12 states.

3.5 Alternative Approaches

The technological optimism of the AA hypothesis derives from Borlaug Green Revolution global previsions, in which agricultural technology would deliver expanding yields and save land for forest recovery (Angelsen & Kaimowitz, 2001a). Interpreted at global scale, the Borlaug previsions are plausible whether gains of agricultural productivity match the increase on demand of agricultural goods. Beyond this point, agricultural production would exceed the demand, and further farmland advances would be avoided. Agricultural production would then concentrate in countries where the factors of production (labor, land and capital) are cheaper

(Angelsen, 1999). In this context it is not surprising the occurrence of FT in temperate developed countries, where rural labor and farmland are quite more expensive, while agricultural frontiers expand in tropical regions (Rudel et al., 2005).

The expanding access of local agricultural products to regional and global markets, as well as the growing mobility of workforce toward distant labor opportunities may entangle local land use decisions and broad-scale variables. The results from the southern state of RS, which apparently corroborate both AA and FT hypotheses, can illustrate this point. Kaimowitz and Smith (2001) pointed out the successful technological adaptation of soybean varieties to tropical conditions as the starting point of mechanization in many Brazilian states. Soybean production started in southern states of Brazil in the early 1960s. The initial yield was very constrained by capital needs for mechanized production. Thus, soybean production was largely benefited by subsidized RC, and then, mechanized soybean croplands replaced traditional labor-intensive cultures as coffee in the south of Brazil.

The possible causation effect of RC on variation of mechanization intensity may be interpreted from an alternative perspective to the FT hypothesis. Rezende (2006) argue that Brazilian rural labor costs have really showed an increasing trend in the decade of 1960. However, this trend was not pushed by competition with new urban labor opportunities, as predicted by FT hypothesis. In that time, rural workers were increasingly benefited by recent labor rights which assured better wages and work conditions.

According to Rezende (2006) the government passed the subsidized RC law in 1965 to compensate farmers for the increased labor costs. This new scenario benefited the mechanization of large farms, which were better prepared to deal with RC requirements. Large farms were widely benefited by scale economies derived from substitution of human workforce by mechanization. The foreign demand for soybean spurred a chain of events on local production in which land prices increased, many southern small farmers sold their lands, soybean mechanized crops took place in the more suitable lands and total farming declined.

The social side-effect was a significant unemployment increase in the Brazilian countryside and many workers migrated to cities (Kaimowitz & Smith, 2001). Although this chain of events corroborates FT and AA hypotheses predictions, migration was pushed by rural unemployment instead of availability of better urban jobs. In this scenario, rural unemployment may increase pressure over marginal lands for subsistence agriculture (Barbier et al., 2010) preventing forest regrowth.

Furthermore, in a sub-national scale perspective, many southern small farmers were attracted by cheaper lands and migrated to the expanding agricultural frontier states as MT. New farmers started to produce soybeans, largely expanding the croplands on Cerrado (Brazilian savannah) and on Amazonian forest (Kaimowitz & Smith, 2001), Thus, contrary to AA previsions, the investments on labor-saving technologies and the improvement of workforce mobility lead to the increase of deforestation (Angelsen & Kaimowitz, 2001b; Walker, 2012).

The contrasting land use results from RS and MT illustrate intertwined effects of migration, mechanization, financial constraints and foreign market opportunities. Similarly, despite the evidence of crop productivity increase leading to FT in the south of the United States, Rudel (2001) admitted that governmental incentives for cotton expansion in the west might have contributed to land retirement in southern region, what clearly illustrates the entangled land use change causation chain.

Agricultural frontiers and regions undergoing FT represent contrasting and complementary scenarios of land use change. This process may be interpreted as a global-scale AA (Meyfroidt et al., 2010) in which economic balance between the factors of production determines what, where and how agricultural goods will be produced. Rural labor mobility and trade of agricultural goods are two relevant exchange channels between agricultural frontiers and FT regions (Walker, 2012). The way these variables contribute to local land use dynamics may be dependent on the interactions of driving forces in both regions (Pfaff & Walker, 2010).

Expanding agricultural frontiers would present characteristics that make agriculture more competitive (as cheaper lands and lower labor costs) as well as cropping advantages (suitable soils, freshwater availability and favorable climate). Meanwhile FT would take place where some combinations of these variables make local agriculture perform worse. Then, if transport costs are low, local demand in these FT regions would be supplied by agricultural goods produced in distant agricultural frontiers (Pfaff & Walker, 2010).

Forest Transition would then promote the recovery of natural areas strictly in less profitable agricultural lands, what would constrain the diversity of ecosystem functions and the supply of ecosystem services. At a global perspective, agricultural frontiers expansion would cause the loss of tropical biodiverse biomes (Barbier, 2004; Hansen et al., 2010) while FT would mainly recover temperate secondary forests (Rudel et al., 2005). This market-driven land use change is unlikely to converge to a reasonable land use pattern capable to supply enough ecosystem services.

In central and southern regions of Brazil large extents of flat terrain with fertile soils became intensive monoculture areas, with low native vegetation cover. This human driven homogenization of landscapes reduces the diversity of habitats and leads to changes in species community composition (Chapter 13, 14, 15, this book). Thus, the ongoing global and regional agricultural adjustments (Meyfroidt et al., 2010) would cause as side-effect some human driven “ecological adjustments”, where ecosystems would be displaced or conserved mainly according their agricultural profitability. Walker (2012) concluded that much of the Atlantic Forest recovery in the developed states of São Paulo (Lira et al., 2012) and Santa Catarina (Baptista & Rudel, 2006) may be supported by imports of forest and agricultural products from Amazonian deforestation. Furthermore, some ecosystem services as watershed balance and nutrient cycling can be profoundly affected by long-distance transport of agricultural goods, since local stocks of water and nutrients are incorporated to exported crops and livestock (MEA, 2005). Obviously, other ecosystem services as carbon storage can be compensated worldwide, despite the carbon content differences among world biomes. However, much of local ecosystem services, as pest control, pollination and soil conservation, can be largely damaged in this economic-driven "ecological adjustment" that does not take into account the importance of ecosystem services and natural capital.

Angelsen and Kaimowitz (2001b) summarized the results of studies in Europe, USA, Latin America, Asia and Africa, which presented some alternative perspectives for predictions of AA and FT hypotheses. The authors argue that economic incentives or subsidies remove financial constraints to farm expansion and may foster deforestation. Thus, to avoid environmental losses, agricultural incentives and subsidies would have to be conditioned to broad-scale assessments of environmental impacts. Fearnside (2008) also considers the restriction of incentives and subsides as a key issue to address rural demographic movements and to improve policies for reducing Amazonian deforestation.

Igari et al. (2009) pointed out that subsidized rural credit plays a pivotal role in recent advance of Brazilian capital-intensive agriculture, given historically increased interest rates. Then, RC policy could constitute an important tool to enforce environmental land use laws as the NFC. In July 2008, the Brazilian Central Bank, the institution responsible for ruling rural credit, inserted environmental criteria for rural credit loans in the Amazon biome (BCB, 2008). In 2012, the reform of NFC softened some mandatory standards for conservation of native vegetation, but it also incorporated a clause that conditioned the subsidized rural loans to farmers in compliance with preservation constraints. It represents a late but promising contribution on stopping government subsidized forest loss. Moreover, it also represents an important step to foster restoration of native vegetation in profitable lands. The restoration actions can increase landscape heterogeneity resulting in better conditions for species conservation in agricultural landscapes (Chapter 6, this book), fostering recovery or enhancement of ecosystem services (Chapter 8, this book).

Rudel et al. (2009) have also proposed alternative pathways to AA and FT hypotheses. Performing meta-analysis, the authors identified changes in the main drivers of tropical deforestation. From 1960 to 1985 rural population growth was the main cause of tropical deforestation, mainly through small farms advance pushed by government incentives. After 1985 capital-intensive mechanized agriculture became the main deforestation driver, and in some cases, urbanization also played a key role in the expansion of agriculture. These results support the idea that the role of mechanization and urbanization, pointed out as two main driving forces in AA and FT hypotheses, depend on the interaction with other broader-scale explanatory variables in land use change pathway.

In agricultural frontiers, better access to international markets, increased mobility of workforce, finance support and mechanization may locally spur expansion of farmland and consequently increase deforestation (Fearnside, 2008). On the other hand, in developed regions the same variables may contribute to FT previsions, since migration to cities increases rural labor costs, and then local produced goods become more expensive, enduring the concurrence with foreign lower priced agricultural goods.

3.6 Final Considerations

This chapter presented a simplified Conceptual Framework that aims to help understanding the economic and social driving forces behind land use change. The Conceptual Framework incorporated particular Brazilian variables as the Forest Code and the Rural Credit law, which might influence the land use decisions in private farms. These laws could foster land sparing inside farms and the adoption of land-saving technologies, what represent a promising scenario to investigate the predictions of Agricultural Adjustment and Forest Transition hypotheses.

The results of the present study did not support AA and FT predictions regarding the causality effect of urbanization and agricultural technology on rural land use change. The predictions of both hypotheses were locally confirmed in some states, however, the analysis of local results must take into account broad-scale connections and fluxes that could mislead the conclusions. The occurrence of FT in one place can be linked to larger deforestation in others, through migration of workforce and trade of agricultural goods. This study highlighted the importance of designing future approaches on land use change analysis that must explicitly deal with explanatory variables as: relative agricultural costs, migratory fluxes and trade of agricultural goods. These variables would capture the comparative aspects that could lead to expansion or retraction of cultivated lands in different regions and then help to understand the connections between FT and deforestation in each of those regions. However, this economic-driven land use change leads to an “ecological adjustment”, where ecosystems are displaced or conserved according to their potential agricultural profitability. Nature conservation would mainly take place in the less suitable lands for agricultural use. This approach is unlikely to converge to a reasonable land use pattern capable to support biological diversity and ecosystem services. Public policies on land use planning, economic incentives and subsides must be capable to integrate agricultural activities and environmental conservation objectives.

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