Land Use in the Amazon from 1950 to the Present

Re-examining Contemporary Land Use and Land Cover Transformations from an Anthropocene Perspective

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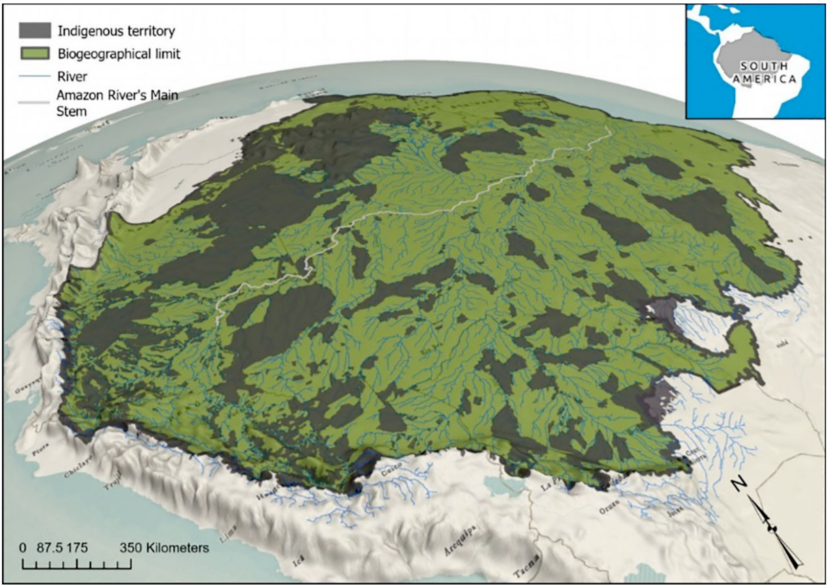
Carrying out a comprehensive and systematic analysis of contemporary land use changes in Amazonia is challenging given the spatial extent, the heterogeneous nature of its diverse ecosystems, the wide variety of land use systems, and the diversity of cultures and land management practices that spread over this region. The Amazon River basin alone is roughly four-fifths of the continental United States (~7,000,000 km²), and vast expanses of its forests have not been studied (Franco-Moraes et al. 2019). Amazonian landscapes are extremely diverse, encompassing *terra firme* (interfluvial) and flooded (riverine) forests, along with wetlands and savannas. Additionally, the Amazon is home to more than 300 ethnic groups, and Indigenous territories occupy about 2.3 million km² of the Amazonian bioregion, about 32 percent of the whole extent (RAISG 2020) (Fig. 1). There is robust evidence that these landscapes have been occupied starting at least 13ka (calibrated years before the present) (Shock and Moraes, 2019; Morcote-Ríos et al. 2020). Despite this diversity and socioecological complexity, popular views of the Amazon River basin continue to push forward two simplistic and opposite but pervasive understandings of this region: widespread deforestation and environmental devastation on the one hand and intact or pristine wilderness on the other. However, both are inaccurate, yet the persistence of these views hampers a more nuanced understanding of a very complex, culturally, and biologically diverse region (Winkler Prins and Levis 2021).

Using the Anthropocene as an analytical framework, this chapter attempts to debunk notions of contemporary devastation of Amazonia and the decline of its pristine forests due to recent human entrepreneurship. Here, I examine contemporary landscape changes in the Amazon region through its land use and land cover dimension, departing from the notion that many of the landscapes that have experienced increased and accelerated transformations in recent decades were not pristine environments in the first place. The Anthropocene view acknowledges that human-modified ecosystems and landscapes currently dominate the Earth and have resulted from centuries, even millennia, of human interventions (Ellis and Ramankutty 2008). Amazonia is not an exception. The Anthropocene lens also allows us to reflect on the "safe operating space" (Steffen et al. 2015: 736). An operating space is here understood not as a tipping point, but rather as a buffer between the boundary and the threshold within these ecosystems that would allow societal development without affecting the resilience and accommodating state of the Earth system. Through this view, researchers acknowledge that most landscapes are in continuous change and have been subject to domestication. In this context, domestication is conceptualized as deliberate human activities that have altered the ecology and demographics of plant and animal populations making large areas of the Earth's lithosphere more productive and hospitable for people (Harris 1989). These areas include significant portions of the Amazon basin as shown by the anthropogenic characteristic of some Amazonian soils (*terra preta*) that resulted principally from pre-1492 human-environment interactions (Woods et al. 2009). The Anthropocene lens also allows us to generate new inquiries and understandings about how, where, and to what intensity social and ecological systems interact (Ellis and Ramankutty 2008), when those interactions are the most intense, and the repercussions of those interactions on the Earth system. Such a framework may also help us understand the non-linear evolution of landscape changes and the carrying capacity of ecosystems, which have generally shown phases of stasis and accelerated change.

Contemporary research on anthropogenic transformations of Amazonian landscapes has focused on the quantification of LULC changes and the factors that induce forest cover reduction (Brown and Pierce 1994; Wood and Porro 2002), a process that results in the loss of biodiversity and forest resources, significant changes in the global climate, and eventually the instability of the Earth system. Because tropical deforestation is caused by humans rather than natural processes, the search for anthropogenic explanations for why this type of human impact has increased in the late twentieth century, and why it has varied in extent from place to place, leads directly to theories familiar to social scientists that still seek answers to these questions in the twenty-first century. Changes in rural populations, their social structures, and their connections to the larger global system are a reasonable place to start (Rudel 1994) in the search for the causes of LULC transformations in contemporary Amazonia. These changes typically lead to a range of intensities of socioecological interactions that affect both natural and social systems and shape Amazonian landscapes.

Fig. 1: The Amazon River Basin Bioregion and Indigenous Territories Covering about 32 Percent of its Extent



Source: RAISG (2022).

Human interactions with Amazonian ecosystems are inherently complex and dynamic (Folke, Holling, and Perrings 1996; Rindfuss et al. 2004) and can result in very different land cover change configurations, ranging from patterns associated with the relatively low impact of subsistence cultivators and hunter-gatherers to the high-pressure exerted by urban dwellers who have replaced pre-existing tropical ecosystems with built environments and permanent infrastructure. Extreme cases of such interactions in places like the city of Iquitos in the heart of the Peruvian Amazon, with almost 500,000 urban dwellers engaging in intense commercial exchanges, the region of Caquetá, Colombia, with more than 400,000 peasant farmers engaged in different forms of cultivation, or the Northeastern Ecuadorian Amazon where remote temporary settlements of uncontacted hunter-gatherer groups with less than 300 members like the Taromenane exist and still rely on hunting, gathering, and basic forms of swidden cultivation for food production, exemplify the broad range of pressures that have transformed and continue to shape Amazonia. These types of interactions have led to characterizing Amazonian landscapes based on the ecological footprint of or pressure exerted by the human groups that occupy these spaces.

The analysis of peasant or colonist farmers (and their agricultural practices and industries) living in relatively new settlements in frontier lands, who are frequently thought of as the main agents of land cover change, particularly during the second half of the twentieth century (Walker et al. 2004; Tritsch and Le Tourneau 2016; Murad and Pierce 2018; Vasco et al. 2018), provides much of the contemporary evidence of the high-intensity impacts of Amazonian inhabitants due to the extent of landscape transformations. However, about a third of the Amazon forests are in Indigenous territories, and there is scant evidence that the impacts of Indigenous peoples or long-term dwellers equate to those impacts caused by recently arrived non-Indigenous agents or that these are subject to the same drivers of change. Many Indigenous territories in the Amazon region lack formal markets, are not bounded by private property concepts, and are rather regulated by common property rules. As a result, the production efforts of Indigenous agents are not necessarily oriented toward profit maximization, as is the case with colonists and urban dwellers. With different production goals, Indigenous households engage in land management practices, behaviors, and interactions that are distinctively different from those found in frontier areas. In this case, the human impact is not necessarily measured by short-term individual agency, but rather the accumulated pressure of several family units transforming the environment over long periods of time.

In this chapter, the Amazonia LULC change processes are described through an Anthropocene lens by examining forest ecosystems as "anthromes" – the term "anthrome" or "human biome" was introduced by Ellis and Ramankutty (2008) to refer to human modified landscapes that have been shaped by direct human interactions with ecosystems. These anthromes are shaped by varying levels of intervention determined by the characteristics of the people who inhabit them, their social structures (endogenous characteristics), and their ties to the larger socioecological system at the national and international levels (exogenous conditions). Through this view, this chapter provides a broad characterization of LULC changes between 1950 and the present based on two coarse, but distinctive landscape arrangements: the ones left by long-term residents and those generated by peasant colonists. However, to better understand this separation, this chapter starts its analysis with how these general patterns of land use emerge in the first place from the overlap of three major conditions: 1) population growth, 3) the need for technological innovation, and 3) integration into the market economy. It is through these differences that a more nuanced understanding of contemporary land use changes and the strategies local populations use to face environmental crises is possible, without falling into dichotomic, simplistic, or stereotypical views of Indigenous peoples as the natural stewards and protectors of pristine tropical forests and peasant colonists as the external encroachers and destroyers of those ecosystems.

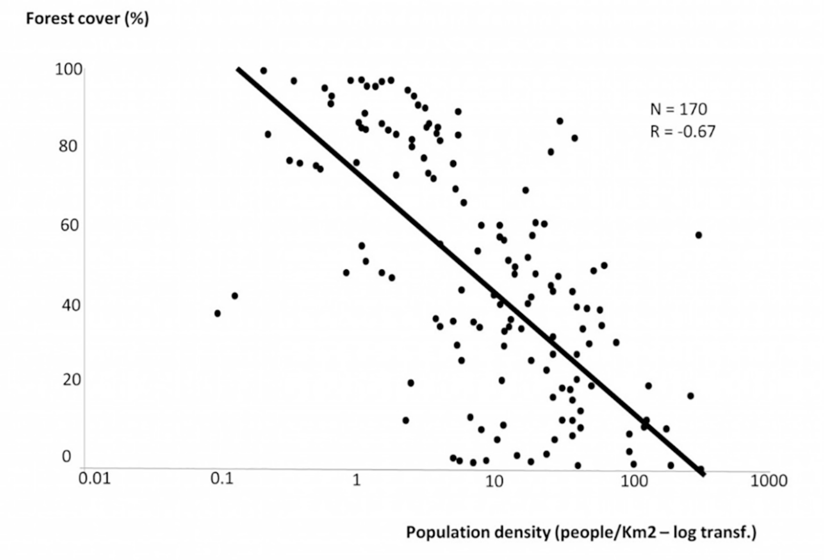
Population Growth as Common Driver of Landscape Domestication and Contemporary Land Cover Transformations

The literature on the effects of population growth on landscape transformations from natural to anthropogenic systems in the tropics is abundant (Bilsborrow 1987; Meyer and Turner 1992; Skole et al. 1994; López-Carr, Suter and Barbieri 2005; Sellers et al. 2017). Particularly in the agricultural change narrative, the Malthusian view has dominated much of the early 1900s debate about agricultural transformation worldwide due to changes in population structure and food production caused by world wars. This view has also played a role in shaping the narrative about agricultural change and its impact on the forest anthrome in Amazonia for a big part of the twentieth century. In *An Essay on the Principle of Population* (1798), Thomas Malthus claimed that population growth would soon outstrip food supply because population grew exponentially, and food supply increased arithmetically. In this view, Malthus pointed out that socioecological transformations in general, and changes humans bring to food production in particular, approach tipping points that promise to slide humanity into starvation and conflict (Kates 1995). In this scenario, the state of technology (an exogenous and fixed condition) determines the levels of cropping intensity and their physical manifestation on the lithosphere. With precarious technology and growing populations, the most obvious and only response to procure nourishment for people is agricultural extensification through the incorporation of new land into the production system. Once agricultural systems reach their carrying capacity (i.e., by the exhaustion of land resources) human populations face starvation, war, or lack of employment opportunities in agriculture, in addition to a consequent pressure for migration to other areas. This situation could lead to environmental alterations that promise to threaten people's survival because according to Malthus' view, the carrying capacity of the environment is also fixed (Ehrlich and Holdren 1988; Kates 1995).

A more recent view that has led to forecasting less gloomy outcomes about the relationship between agriculture change and population growth was introduced by Esther Boserup in her book *The Conditions of Agricultural Growth* (Boserup 1965). Boserup contended that population increases trigger agricultural growth when human groups switch from extensive to intensive practices, as changes in population factors (mostly population pressure or density) push for innovation and technological shifts (an endogenous outcome), which in turn allows for the growing population. For Boserup, food production systems evolve from extensive to intensive forms, which could translate into LULC transformations (e.g., when land use changes from pastures for cattle raising, requiring a low amount of labor per unit of area, to soybean or African palm cultivation, requiring significantly more). This transition could be better explained as the result of differences in population growth and the capacity of human populations for technological innovation, which in turn, increases the human carrying capacity of the environment. This can be achieved not only by extensification (i.e., increasing the area under cultivation but keeping yields constant per unit of area) but also by intensification (i.e., increasing yields per unit of area and keeping cultivation area constant), with the adoption or development of new technologies. In general, land use extensification can be thought of as an indicator of labor efficiency and only occurs in systems where land is abundant and available, with relatively low population densities. Increases in population, and thus in the amount of labor, allow extending agricultural area first (i.e., to clear forest and prepare land for cultivation). An extensive agricultural system may be an efficient means of land management since increases in labor input reduce the time required for clearing larger areas. As frontier lands are reached and marginal land is brought into cultivation, the returns to labor from extension of area decrease. The result is a shift from extensive to intensive cultivation strategies, such as from rotational to more permanent types of land use systems (e.g., from forest fallow to annual cropping systems) (López-Carr 2004). Several researchers have studied this type of evolution and specifically pointed out the positive linkages between population growth and agricultural intensity (Turner II and Ali 1977; Ruthenberg 1980; Pingali, Bigot, and Biswanger 1987; Smith et al. 1994; Tiffen, Mortimore, and Gichuki 1994). Although these authors noted that population density accounted for most variation in agricultural intensity, other factors such as market integration, cultural pressures, and environmental constraints also merited consideration.

Although Malthusian and Boserupian theories may seem to lie at opposite ends of the agricultural change spectrum, Lee (1986) and Turner and Ali (1996) suggest that they do not necessarily contradict each other. They still share various assumptions about the relationships among population, technology, and resource use intensity, but differ in their views of the origin of technological innovation. Malthus implies that technological innovations are exogenous in that their development is not necessarily ingrained in the population pressure condition. Boserup grounds this development directly into that condition. Thus, technological change is endogenous to the socioecological system. Furthermore, because population growth (i.e., a key variable for both Malthus and Boserup) is common in regions experiencing agricultural change like the Amazon region, it is currently accepted in the literature as a significant driver of forest cover change in the tropics (Geist and Lambin 2001). However, it adds little explanation to how and why changes occur in the first place. In fact, the general existence of population growth and human mobility in these regions can confound interpretation, as they are frequently the only shared traits across separate regions (Keys and McConnell 2005). Thus, contemporary explanations about LULC changes in areas with varying population densities like Latin American countries in general, (Fig. 2) and the Amazon region in particular, usually point at population pressure as a major force but usually concatenated to a series of interacting political, economic, and ecological factors acting across different scales (Geist and Lambin 2001).

Fig. 2: Negative Correlation between Forest Cover and Population Density using a Sample of 170 Observations collected in the Second Half of the Twentieth Century in Subnational Districts across 13 Latin American Countries



Source: Palo (1994).

The general acceptance of multi-factor causation of LULC in the neotropics has led to an explosion of studies investigating the proximate causes and underlying forces of LULC change in the tropics and elsewhere (Rudel and Horowitz, 1993; Brown and Pearce 1994; Angelsen and Kaimowitz 1999; Lambin, Geist, and Lepers 2003; Grainger 2013).

Although it is now well understood that proposing single-factor causation explanations of land cover changes in tropical environments is naïve to say the least, using the population growth framework as a departure point for explaining land use change processes in the Amazon region in contemporary times is still a worthwhile exercise, particularly in the context of the Anthropocene. Population growth theories applied to environmental change allow for 1) meaningful characterizations of anthropogenic landscapes at different stages of intervention, 2) identifying links with technological innovation and the adoption of intensive or extensive cultivation practices, and 3) connecting aspects of market integration and demography. This framing also restrains popular subjective views of pervasive devastation of pristine landscapes by some human groups or promotion of environmental stewardship and protection by others based on cultural differences despite their ecological importance. The following sections focus specifically on the Amazonian case and the role of population growth, technological innovation, and changes in economic behavior and demography in shaping LULC changes in a complex socioecological region. The section starts the discussion with a rather simplistic separation of spatial patterns associated with the length of human occupation of landscapes with a particular emphasis on their evolution since the second part of the twentieth century.

The Indigenous Land Use Footprint and Environmentalist Narrative

Until the 1950s, most indigenous Amazonian groups such as the Jívaro (Ecuador and Peru) Huaorani (Ecuador), Campa (Peru and Brazil), Asháninka (Peru and Brazil), Záparo (Ecuador), Tsimane (Bolivia), Yanomami (Venezuela and Brazil), Machiguenga (Peru), and Tikuna or Tukuna (Brazil, Peru, and Colombia) still lived in dispersed, temporary, and very low population density settlements (Moran 1993; Taylor 1999; Godoy 2001; Doughty Lu, and Sorensen 2010). Although there is robust evidence that the dispersed, temporary, and low-density characteristic of Indigenous settlements was not necessarily the norm in the Amazon basin at the time of arrival of European settlers to the Americas in the late 1400s and 1500s (Denevan 1992; Moran 1993; Clement et al. 2015; Levis et al. 2018), most contemporary land use changes in Indigenous territories have been linked to accelerated nucleation (or re-grouping) processes of relatively isolated, dispersed, low-density, and semi-nomadic populations during the second half of the twentieth century. The relative isolation and dispersion of native groups that characterized "wild" Amazonian landscapes until the 1950s resulted from decades and even centuries of persecution of Indigenous peoples who fled into forested areas to escape the violence unleashed by European settlers and their descendants. The impact of epidemic diseases introduced during the European conquest, which decimated up to 95 percent of native Amazonians in the first century of contact, also contributed to the low-density and dispersed characteristics of contemporary native Amazonian societies (Porro 1994). The nucleation of Indigenous Amazonians after the arrival of Europeans was mostly induced by missionaries and slave owners as a strategy to group natives around missions to facilitate catechization and secure labor. These processes are not new, and the literature suggests that such efforts started in the 1600s as part of the assimilation strategies imposed by European rule (Taylor 1999). However, the transition from dispersed and semi-nomadic Indigenous settlements to nucleated and permanent villages in the past five or six decades is probably the most important characteristic associated with long-lasting landscape transformations in ancestral territories in contemporary times (Descola 1994; Sirén 2007; López, Beard, and Sierra 2013). In the modern history of Amazonia, for example, these changes correlate with population growth and the increased influence of external agents (e.g., religious missions, urban markets, agro-industries, or national development policies) that have continued promoting the grouping of families and production areas in clustered arrangements (Rudel, Bates, and Machinguiashi 2002; Taylor 1981). By adopting a nucleated living and production arrangement, population pressure has significantly increased in and around settlements, which has led to patterns of land use distinctively different from those that originated under conditions of dispersion and low population densities in the previous centuries.

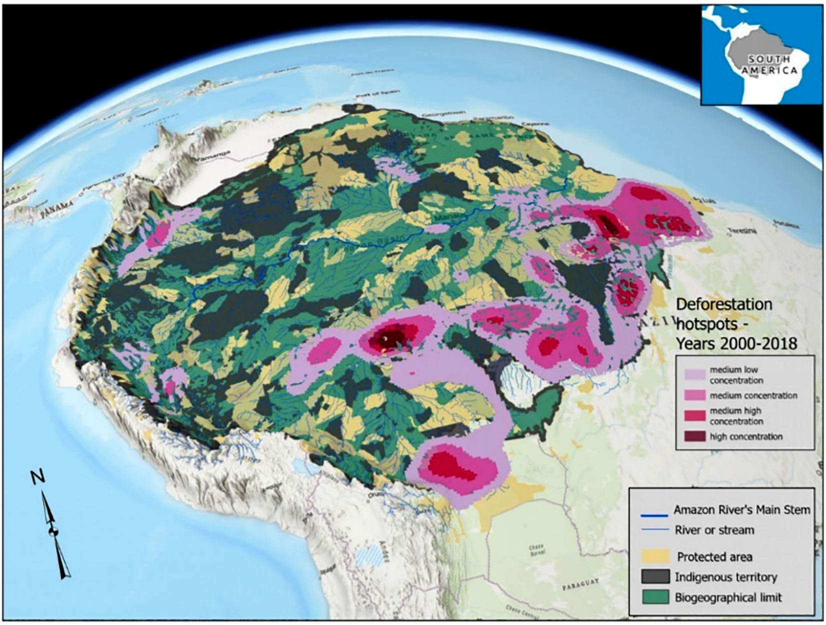
Nucleation is slowly transforming Indigenous people from mobile resource users to sedentary cultivators, causing permanent changes to Amazonian ecosystems and a more distinctive contemporary footprint. Some Indigenous groups like the Kichwa, Shuar, Achuar, and Machiguenga of Western Amazonia have also adopted extensive production strategies like cattle raising, which has prompted the incorporation of newly cleared land (i.e., increased deforestation) into the production system and triggered the conversion of old swidden cultivation areas and fallows into pastures. Raising livestock has contributed to the sedentary character of today's nucleated settlements because, unlike the swidden agricultural plots, pastures are more likely to remain in the landscape for a few decades, given the significantly high costs of labor, time, and agricultural inputs of creating them (Lopez, Beard, and Sierra 2013).

But why would Indigenous people now embrace nucleation if it was used as a social control and indoctrination mechanism by external agents and is also causing a more permanent mark on the landscape? As stated earlier, nucleation is not new but has accelerated since the 1950s because of external factors. It is currently a general strategy adopted by Indigenous groups to regain control over their territory and resources through evolving sociopolitical structures and new production strategies (Lopez, Beard, and Sierra 2013). Indigenous populations in Amazonia are growing (McSweeny and Arps 2005) and most live in permanent or semi-permanent nucleated settlements. Changes in social structures allow Indigenous people to access resources inside and outside their controlled territories, and in many cases, facilitate easier integration into the market economy (Jackson et al. 2001; Diamond 2005) since nucleation allows for territorial claims, land control, and all the benefits associated with land access (e.g., improved communication with the outside world, or access to resources). Entering the market economy allows Indigenous households to increase their level of food consumption, reduce variability in food consumption, access foreign goods and innovate (Godoy, Reyes-García and Huanca 2005). The market economy, especially since the 1950s, has taken a different shape as global trade started to show a higher share of merchant production, a significant growth of the trade in services, the rise of production and trade by multinational firms, and a continued removal of obstructions to the movement of goods and services to create perfect conditions in which international trade can expand (Blouet 2004: 7). All these changes have affected economic relationships globally, including those with and within rural areas, which is slowly affecting how and for what purpose Indigenous peoples produce. The re-orientation of production from subsistence to market-oriented, from low-yield to high-yield, with the adoption of modern technologies (e.g., modern machinery, communication infrastructure, or improved weeding techniques) has been associated with distinctive LULC patterns in Indigenous Amazonian territories since the 1950s.

Despite these transformations, the impacts of contemporary Indigenous agents on land cover have been generally low in comparison to their non-Indigenous counterparts for most part of the twentieth century. Because of this and the extent of many ancestral Amazonian territories, current debates about the fate of their territories and the forests within have been bound with aspects of conservation, pushing forward the notion of Indigenous peoples as the stewards of the rainforest and their important role in the global conservationist agenda. However, a purposeful and deliberate collaboration between Indigenous movements and environmentalist organizations is partly responsible for this type of narrative (Davis and Wali 1994). In 1990, a year of re-evaluation of the relationships between Indigenous and Non-Indigenous peoples after 500 years of the arrival of Europeans in the Americas (Dietrich 1992), the *Coordinadora de las Organizaciones Indígenas de la Cuenca Amazónica* (COICA) organized the First Summit of Indigenous Peoples and Environmentalists in Iquitos, Peru. Later international agreements, including the Rio Convention on Biological Diversity, made it clear that these linkages were relevant in tandem with the "close and traditional dependence of many indigenous and local communities embodying traditional lifestyles on biological resources, the desirability of sharing equitably benefits arising from the use of traditional knowledge, innovations, and practices relevant to the conservation of biological diversity and the sustainable use of its components" (United Nations 1992).

Presently, most of the territorial claims made by Indigenous peoples are based on such a conservationist ideology, which many groups have purposedly appropriated. This link to environmentalism, an important social movement that started in the 1950s and 1960s in the Global North, is questionable and has, to some extent, also jeopardized the legitimate claims of Indigenous peoples to their ancestral lands and natural resources since the 1960s, regardless of its ecological significance. Indigenous peoples, however, have some unalienable rights to the land and other natural resources because of their previous territorial occupation, which nation-states normally see as their exclusive rights. While their views on conservation and sustainable development frequently diverge from those of environmentalist groups, the environmental agenda considers the fact that Indigenous peoples depend on the preservation and management of their environments for their survival (Redford and Stearman 1993). At the same time, robust evidence exists that Indigenous Amazonian territories currently serve as *de facto* protected areas since they still contain significant amounts of forests and biodiversity and that most significant land cover changes in the past fifty years have occurred mostly outside these areas (Fig. 3).

Fig. 3: Concentration of Deforested Areas (in red and pink tones) in the Past Two Decades. Most intense Land Cover Transformations have occurred outside Indigenous Territories and Protected Areas in the Amazon Region



Source: RAISG (2020).

Although protecting Amazonian landscapes is a noble goal with significant socioecological benefits for the Earth system and humankind, the way environmental organizations, particularly those from the Global North, have framed these conservation efforts in the past sixty years has been and is problematic. The rights of Amazonia's long-term residents to their territories and natural resources are essentially being undermined when conservation programs treat the region as a "pristine" ecosystem or as the ultimate wilderness frontier. The Anthropocene lens could contribute to reframing this perception by promoting the view that Amazonia, despite being a humanized landscape, is still worthy of conservation. In fact, beta diversity of some living forms, especially plants, has increased as a result of various kinds and degrees of human modifications of Amazonian ecosystems (Odonne et al. 2019). Moreover, food resources and agrobiodiversity are usually highly concentrated in domesticated forests, a condition that is valued by both human and non-human populations (Junqueira, Shepard, and Clemente 2010; Levis et al. 2020). As noted earlier, the Anthropocene framing allows for a meaningful re-conceptualization of the conservation and development in Amazonia through the eyes of its long-term residents.

The Colonist Farmer Footprint and the Frontier Land Narrative

The most intense socioecological interactions in the Amazon region during the last six to seven decades have been driven regionally by processes of frontier land occupation. Frontier land occupation has been a strategy used by governments in Latin America to advance their development and geopolitical agendas with different levels of success. In-migration to frontier areas is perhaps the main source of population growth (Lutz 1996) and a precursor of agricultural extensification and intensification. Frontier lands encourage in-migration because they open up possibilities for land accessibility, tenure, and material production. These processes are of particular interest to researchers because they usually lead to fast and ubiquitous biophysical transformations including forest loss (Tab. 1). Because of their celerity, these changes threaten the integrity of rainforests and the ecological services they provide if no enforceable restrictions to clear forests are applied. Recent efforts to identify areas at risk of significant forest loss due to concerns of environmental degradation caused by anthropogenic activities in the Amazon have concentrated on the identification of deforestation fronts and hotspots. The term “deforestation hotspot” has been used in the LULC change literature to define areas with particularly high rates of deforestation in a given time period. A deforestation front can include one or several deforestation hot spots (Kalamandeen et al. 2018; Pacheco et al. 2020; RAISIG 2020).

Tab. 1: Deforestation Extent by Amazonian Region/Country between 2000 and 2018

Country	**Original forest cover extent (km²)**	**Cumulative deforestation until 2000 (km²)**	**Percent of the original forest 2000–2013 (%)**	**Cumulative total (%)**
Bolivia	333,004	14,035	3.1	7.3
Brazil	3,587,052	458,500	4.8	17.6
Colombia	465,536	34,673	2.4	9.9
Ecuador	97,530	9,343	1.2	10.7
Guyana	192,405	3,097	0.9	2.5
French Guyana	83,195	1,539	1.0	2.8
Peru	792,999	55,649	2.0	9.1
Suriname	150,254	5,664	0.4	4.2
Venezuela	397,812	8,914	1.0	3.3
TOTAL	**6,099,788**	**591,414**	**3.6**	**13.4**

Source: RAISG (2020).

In the Amazon basin, deforestation fronts have been shaped by in-migration processes that share common characteristics. López-Carr (2003) asserts that these have been, for instance, led by peasant farmers who migrate to live in a remote, disease-ridden forest frontier, and cultivate crops with little to no public infrastructure or services with limited technology and unstable environmental conditions, leaving behind better-paying and more diverse labor markets, public education, health care, and community infrastructure. The fact that these migrants, perhaps paradoxically, assert that their current circumstances are better than those in their home regions or countries (López-Carr 2002; Billsborrow, Barbieri, and Pan 2004) emphasizes the strength of the one attraction that frontier environments have to offer compared to other possible destinations: land. Land accessibility provides a sense of security and is an attractive investment, especially when accompanied by government or individual promises of land tenure or ownership. Examples of fast forest conversion as a result of this phenomenon include: 1) The Northern Ecuadorian Amazon, where population grew at annual rates exceeding six percent through the 1970s and 1980s, and slightly decreased to about five percent in the 1990s and 2000s (Southgate, Sierra, and Brown 1991; Bilsborrow, Alisson, and Pan 2004). Here, the agrarian reform of 1964 and its subsequent expansion in the 1970s generated significant in-migration to the Napo region, in the provinces of Sucumbíos and Francisco de Orellana. This in-migration was both spontaneous and planned and resulted in thousands of people from impoverished areas in the Andes moving into the Amazon basin. 2) The Brazilian Amazon where high deforestation was closely linked to high levels of in-migration in the 1960s and 1970s (Wood and Porro 2002). Frontier land occupation was formally labelled as Operation Amazonia (Wood and Schmink 1993; Dias 2019) and promoted during the military dictatorship in 1966 due to national imperatives to incorporate the Amazon region into the national economy and gain geopolitical sovereignty. Similar processes have been also observed in the Bolivian Chapare region and more recently near Madidi National Park (Cordona Locklin and Haack 2003), Peruvian Central Amazonia (Machiguenga territory) (Emlen 2020), and Colombian Caquetá River region (Holmes, Pavón, and Gutiérrez de Piñeres 2020), to name some of the most significant examples.

Amazonian frontier lands in the twentieth and twenty-first centuries have been characterized by rapid transitions from extensive to intensive, and sometimes intensive to extensive land use systems depending on the evolution phase of frontier households. Contrary to Boserupian theory, recent case studies from more developed frontiers in the Amazon basin typically show increasing extensification and forest loss along with agricultural intensification caused by population growth (Pichón 1997; Angelsen and Kaimowitz 1999; Perz and Walker 2002). For example, in a recent national level study in Brazil, Tritsch and Le Tourneau (2016) found that agricultural extensification occurs in areas with low population densities, and areas with quite high population densities experienced the contraction of agricultural land use. In certain cases, this latter dual process at the farm level appears to be driven by the relatively wealthy households that are able to afford intensification in the form of hired labor, agricultural inputs, tools, and equipment, as well as able to expand agricultural land holdings (López-Carr 2003).

Frontier land in-migration commonly happens simultaneously with other development strategies like road expansion and the consequent opening of local and national economies (Chomitz and Gray 1996; Pfaff 1999; Lopez and Maldonado 2023). In Brazil, for example, the construction of roads since the 1950s has been commonly identified as a proximate factor of LULC change, and it is well known that most deforestation in Brazil occurs in areas within 50 km from a road (Chomitz and Thomas 2001; Asner et al. 2006). Barber et al. 2014 found that nearly 95 percent of all deforestation occurred within 5.5 km of roads or within 1 km of navigable rivers. Similar patterns have been observed in Peru, Ecuador, and Bolivia (Gallice Larrea-Gallegos and Vázquez-Rowe 2017; Lopez 2022), with intense deforestation processes happening at even shorter distances. The construction and expansion of road networks since the mid-1950s also led to the slow opening of South American national economies, giving place to an agro-industrial period. This transition pushed forward economic agendas with development plans for the Amazon that not only focused on establishing human presence in sparsely populated areas and providing food for nourishment purposes of local populations, but on augmenting agricultural production (licit and illicit) for commercial purposes (e.g., soybeans, African palm fruit, pastures for cattle raising, coca leaves) in a market-oriented and more globalized economy. For example, in cases like Bolivia (Santa Cruz) mechanization processes took place in the 1960s to reach industrial production levels of soybean, sugarcane, and rice, and in Brazil (Mato Grosso) in the 1970s, soybean was introduced as a cultivar alternative to overcome the issue of impoverished soils, particularly in the forest-savanna transition region in the south. In Brazil alone, soybean production extent increased 57 times between 1961 and 2002, while production volume increased 138 times. Since the year 2000, soybean harvested area in Brazil has increased by 160 percent (FAO 2019), most of it in the Amazon basin. Since the early 2000s, at the Pan Amazon level, forest reduction associated with other industrial-level processes like large-scale cattle ranching for meat and milk production following phases of frontier land occupation has constituted a significant human impact more recently. The contribution of cattle ranching to the overall forest loss in the Amazon, for example, probably reaches around 80 percent (RAISG 2020), particularly in transitional regions and savannas in Brazil and Bolivia, where soybean monocultures dominate the agricultural landscape. Soybeans are commonly used as animal feed worldwide.

In addition to soybeans, the increased production of other agricultural commodities in the Amazon region and the associated LULC transformations in the past couple decades respond to current global demands in the agricultural sector (Lopez 2022). African palm cultivation, for example, is another important agro-industry affecting land cover and driving accelerated land use changes in the Amazon in the past two decades, particularly in Upper Amazonian countries like Colombia, Ecuador, and Peru. The expansion of African palm cultivation is another conspicuous land cover transformation that has intensified since the 1980s due to not only the development of road infrastructure in the region but, more importantly, the increased global demand for palm oil. Global palm oil production has doubled every 10 years since the 1960s and has become the world's dominant vegetable oil (Gaskell 2015; Butler and Laurance 2009) followed by soybean oil (Song et al. 2021).

In the early 1970s, important regions of the Meta, Guaviare, Putumayo, and Caquetá departments in Colombia became production centers of coca to satisfy the global demand for illicit drugs like cocaine (Holmes, Pavón, and Gutiérrez de Piñeres 2020). Large areas of Peru, like the Valle del Alto Huallaga, were quickly integrated into this illicit global economy during this time, and the extensification of coca production led to significant landscape transformation in the valley (Paredes and Manrique 2020). Similarly, in the Chapare region in Bolivia, a well-defined coca frontier was established between 1940 and 1990 with the in-migration of thousands of colonist farmers (Millington 2020). Other industrial operations that have also led to frontier land occupation in the Amazon include oil production, mining, and logging, processes that in most Amazonian countries also started on a larger scale in the 1970s, facilitated by the construction of roads.

These cases exemplify a regional trend in which states promoted large-scale settlement projects to occupy frontier lands by developing roads and expanding the agricultural frontier. With road infrastructure in place, the penetration and expansion of industrial resource extraction activities of different kinds was possible. In most cases, these investments involved international development agencies and donors and ultimately opened the Amazon frontier – a contested space incorrectly conceptualized as “empty” – to millions of poor landless Andean peasants. The long-term impacts of these processes are now visible from space, and land change researchers in the late twentieth century and early twenty-first century have spent significant efforts trying to infer transformation processes from such ubiquitous spatial patterns (Arima et al. 2013; Simmons et al. 2016; Ball et al. 2022; Lopez 2022).

With population growth, changes in social structures and household life cycles usually follow. Such changes have been identified as important drivers of land cover transformations in the late twentieth century and twenty-first century in Amazonia (Walker et al. 2002). In this context, Chayanovian theory (Chayanov 1986) has been a useful framework to analyze land use cover changes associated with household demographic factors in the Amazon basin. According to this perspective, the age and sex composition of households affects labor and, therefore, land use and forest conversion. By accepting that household effects are universally important, the difference between Indigenous and colonist ecological footprints shortens. In both cases and despite the considerable geographic variation, a general land use change process associated with household demographics appears to recur throughout the Amazon basin as a product of sedentarization. The family cycle begins with migration to either a new farm plot or human settlement. New arriving families tend to have household heads and spouses in their twenties and thirties, typical reproductive age, with no or small children. Forest clearing and cultivation expansion occur during the first several years of settlement as forest is initially cleared for the opening of cultivation plots, gardens, pastures, demarcate land occupancy, and claim resource use rights. As families grow and the relationship between household consumers and producers change, the pressure on forest will also change, with higher consumer-to-producer ratios demanding more agricultural production, which could be obtained through extensification if technological innovations are not possible (e.g., in autarkic Indigenous territories) or intensification if technology is available (e.g., inaccessible frontier-lands). As the household evolves, the increasing labor supply of maturing children and financial stability induces further expansion into new cultivation efforts (Perz, Walker, and Caldas 2006). Larger households may opt for more intense land uses as available forest land is diminished on the farm or community, and increased labor may encourage intensification. Conversely, smaller households with higher consumer-to-producer ratios may be encouraged to purchase cattle due to the low labor demands of maintaining pasture. As children become adults and the consumer-to-producer ratio drops due to out-migration of young adults to other forested areas, villages, or cities, the demand for crops also decreases locally, which will eventually result in LULC changes.

Studies in both colonization frontiers (Pichon 1997; Brondizio et al. 2002) and Indigenous territories (Godoy 2001; Lopez, Beard, and Sierra 2013) in the Amazon have shown the effect of household life cycles and demography on land use and land cover not only in the aftermath of large-scale frontier occupation projects but also after small, nucleated settlements are formed. Household life cycles have played an important role in shaping contemporary landscapes across the Amazon basin and partially explain the non-linear characteristic of LULC changes. Of course, household life cycles account for demographic changes that, at the same time, are affected by other underlying institutional and political drivers acting at different scales.

Conclusions: The Anthropocene as an Analytical Framework of Contemporary Landscape Transformations in Amazonia and Beyond

The Anthropocene perspective allows us to understand Amazonian landscapes as places of significant human transformations and pressures in continuous evolution, in contrast to a perceived "intact," "pristine," or "in balance" wilderness. By adopting this view, the divide between notions of culture and nature is to some extent arbitrary. For Kawa (2016: 19), for example, within Amazonian landscapes "the separation between the human and non-human [...] has grown increasingly fuzzy, to the point that it is rendered almost meaningless." What the Amazon region experienced in the past 60 to 70 years is the intensification of human-environmental relationships, mostly triggered by population growth, but concatenated to a series of economic, demographic, technological, political, and institutional pressures acting at different spatio-temporal scales. Both Malthusian and Boserupian theories of agricultural change have played a significant role in explaining contemporary LULC changes in the Amazon region. These theories do not contradict but rather complement each other, as they allow the description of transitions from extensive to intensive systems and vice versa, depending on the developmental stage of households. Contemporary patterns of LULC change in the Amazon are a reminder that landscape transformations are not linear, but correlate to cycles of population growth, social changes, political processes, and institutional reforms in a more globalized economy.

From a development point of view, the Amazon region must be reconceptualized as a dynamic *anthrome* or humanized landscape, with different levels of intervention. The region is dominated by LULC arrangements in continuous change, with periods not only of intense transformation, like those experiences in the last few decades, but also of stasis (Denevan 1992). The pristine forest narrative has undeniably led to the "empty land" discourse used by governments and developing agencies since the

1950s to justify planned and spontaneous occupation of Amazonian frontier lands by external agents. This discourse has been the base of not only nation-states' strategies to gain control over large territories but served as a tool to undermine Indigenous peoples' rights to their ancestral lands and their natural resources. The pristine forest view has also been used by environmentalist groups to put forward conservation agendas that exclude people or do not take into account people's needs, through the promotion of Amazonia as a biome of mostly ecological value essential to maintain critical ecosystem services for the Earth system (i.e., as a global climate regulator), a storehouse of yet to be discovered biodiversity that could eventually lead to unprecedented breakthroughs in Western medicine and other sciences, and as the last wilderness frontier waiting to be discovered by intrepid explorers or modern researchers (Winkler Prins and Levis 2021). Amazonian landscapes are not untouched or just waiting to be revealed to the outside world; rather, they are humanized environments that will be further transformed by ever-evolving human-environment interactions. This does not mean that they are not worthy of conservation, but what needs to be considered and what makes the Anthropocene a constructive framework is that conservation efforts should not be built upon un-revised notions of a wild Amazonia. The Anthropocene also highlights the need for conservation strategies to consider human needs and well-being as integral components of any protection and management initiative of Amazonian landscapes. This could lead to more inclusive and long-term solutions that address both social and ecological challenges simultaneously.

As Indigenous landholders and frontier settlers gradually become incorporated into the national economies and their needs become fully articulated in development plans, a careful examination of the structure of their production systems and emerging social structures can contribute to the formulation of adequate regional land development and conservation policies. These efforts should include diverse understandings of natural resource management and food production, in addition to grounded interpretations of the socioeconomic needs of local communities, their organizational socioecological structures, and their adaptive capacity. This step may be an important condition toward guaranteeing the sustainability of Amazonian socioecological systems in the long haul.

In conclusion, the Anthropocene framework challenges conventional ways of understanding the lithosphere, development, and conservation paradigms by highlighting the interconnectedness between humans and the environment. This framing enables an understanding of Amazonian ecosystems as humanized landscapes while promoting a more integrated and flexible approach that prioritizes the conservation of socioecological systems, as opposed to pristine biomes in the face of accelerating environmental change. This can be done through the integration of techno-scientific and traditional ecological knowledge systems, considering both ecological and social elements simultaneously. The Anthropocene framework also contests notions of a fixed carrying capacity with well-known planetary boundaries and tipping points. With new technologies and changes in human behavior on a global scale, such limits may be hard to delineate or accurately quantify since they may be modified over time. Still, regulation and continuous evaluation of human impacts should be framed in the context of "safe limits," in which both ecological and human systems continue to thrive and develop (Steffen et al. 2015). Further work to monitor land cover changes and their impacts on ecosystems is needed to be able to determine what these buffers are and the anthropogenic pressure thresholds below which the probability of the Earth system becoming unstable remains low.

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